Braiding machinery

By W. Weber-Partenheimer

Textile terminology is often lacking in precision, so that when in the course of history new processes have evolved in parallel one name may come to be used for several quite distinct techniques. Braiding is a case in point. Knitting, too, is a general term which covers a number of different processes; so it may be as well to start with one or two descriptive definitions.

In textile terms, braid in the widest sense is fabric formed by the interlacing of threads diagonally to the axis of the material. The simplest form of braid is a three-strand plait (Fig. 9). The point at which the strands cross is known as a stitch or pick, and the line of stitches along the length of the braid is a rib. Braids can be characterised by the number of stitches per unit of length and the number of ribs across the width.

In simple mechanical braiding the spools move on a fixed serpentine track. In lace braiding the strands are twisted as well as interlaced (Fig. 10), and the movements of the spools or bobbins are controlled individually by a jacquard. Some of the spool carriers may be temporarily disengaged as required by the pattern, and at least two pairs of threads are needed, as the diagram shows, to make up a primary binding.

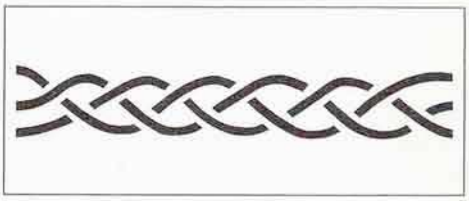
Knitted fabrics are of two basic types: weft and warp knit. A plain stitch weft knit fabric is formed with a single yarn running horizontally. Each needle forms its own loops, and each course or row of stitches is formed by interlooping the yarn with the loops of the previous course, as in hand knitting (Fig. 11). In warp knitting, a chain stitch or tricot is formed by intertwining a number of vertical threads, and the yarn is laid round the needles by separate thread guides (Fig. 12). Two forms of warp knitting machines, crochet and raschel machines, are used respectively for net and lace, which are discussed in a separate article on page 10.

Mechanical braiding

To form a three-strand plait on a machine, six "holders" are required, in three of which the strands (or their corresponding spools) must somehow be held so that they can be mechanically transferred in due rotation to the other three holders and back again. The repetition of this process gives the characteristic plaiting sequence of one holder occupied, one empty. On a braiding machine these holders are slots in the top plate of a special type of gear known as a horngear. Figure 13 shows how the slots are arranged to coincide as the wheels of the gear rotate in opposite directions. As each spool or spindle carrier is transferred from one wheel to the other, the contrary motion carries it round in a figure of eight, and the strands become interlaced to form the plait or braid. This is the simplest form of braider. The number of slots, and the number of gears, can of course be increased to make flat or tubular braids or solid cords of different widths or diameters.

Maypole braiders

A braiding machine can be described in simple terms as an assembly, known as a deck, of two flat metal



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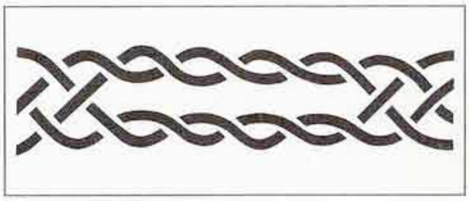
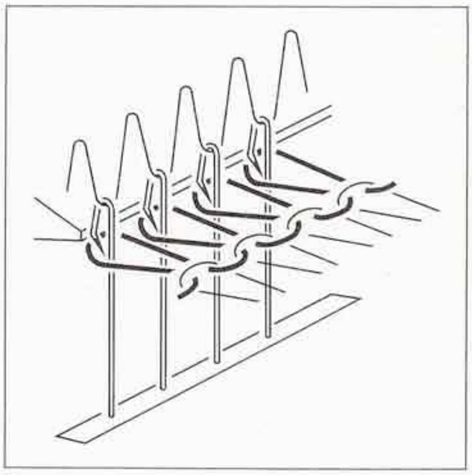
Three-strand plait.

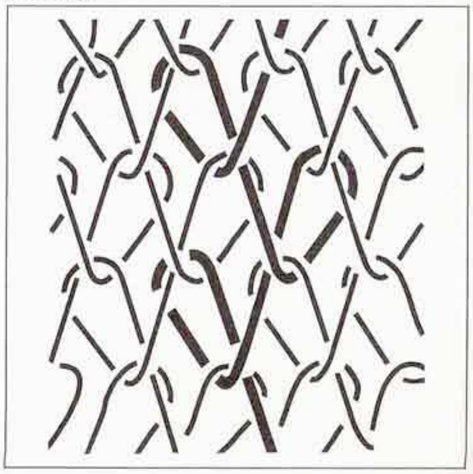


10
Lace made with two pairs of strands, plaited and twisted.



11
Loop formation in weft knitting.

12
Loop formation in warp knitting.



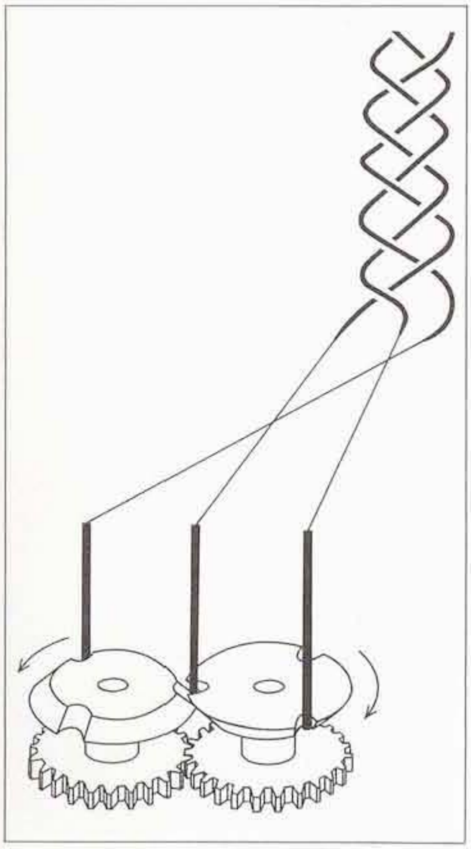
plates bolted together with a train of horngears between them. The gears are arranged to propel the spool carriers round a double track which is cut in the upper plate to form a succession of figures of eight. The yarns coming off the moving spools meet at the "braiding point" on a centrally mounted former, and the finished braid is drawn off continuously at a uniform rate by a roller connected to a change gear system. It is then delivered into a can or wound on to a drum (Fig. 14). For tubular braid the track completes a circle round the braiding point, and the path traced by the carriers is exactly similar to that of the dancers round a maypole, who are in fact "braiding" their ribbons on the pole; hence the common name for this type of machine (Fig. 16). In flat braiding the track does not complete the circle, as can be seen in figure 14; at the point where it is interrupted the carriers are reversed by two (usually larger) terminal gears.

Maypole braiders are built either on the carried carrier system, in which the carriers actually ride on the horngears, or on the slide plate or Barmen system in which the carriers sit on the track plate, and the horngears simply propel them round the track. The disadvantages of the slide plate system, such as higher energy consumption, the need for more frequent lubrication, heavy surface wear and more noise, have been largely overcome by the development of moulded plastics gears and carriers.

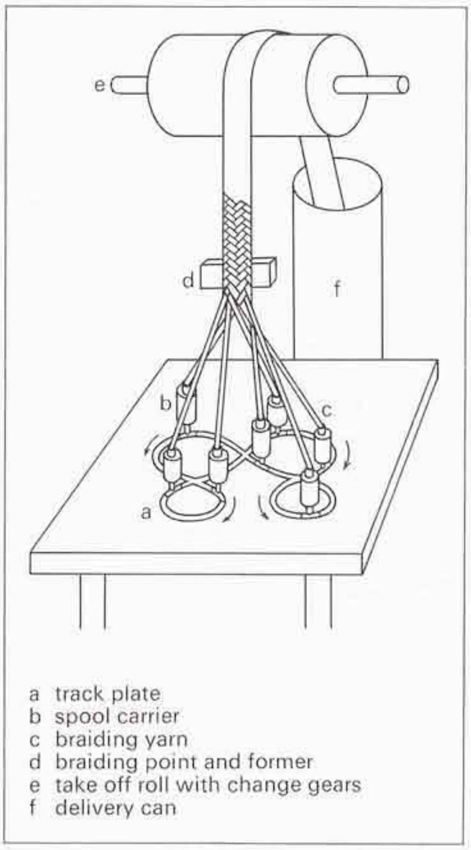
As the carriers travel round the track they are moving radially in and out so that the distance from any one spool head to the braiding point is constantly changing. It is a function of the carrier, as it pays out the thread, to keep it under constant tension. On the older type of carrier this is done by means of a simple drop weight, either an external weight as shown in figure 15 or one enclosed in the tube on which the bobbin sits. As it slides up and down the carrier stem according to the distance of the carrier from the braiding point, the weight activates a supply release pawl or "dropper", which engages in a ratchet on the bobbin head. Modern braiders have spring tension carriers, which make higher running speeds possible.

Braid sizes and types are determined by the number of carriers and by the horngear "pitch", which is the distance (in mm) between the axes of a pair of horngears, and is thus governed by the diameter of the gear: the wider the gear the bigger the yarn package it can accommodate. Unfortunately there are as yet no recognised standards for pitch.

Specialised braid patterns are largely determined by the forming bar. Formers are used in great variety for making different types of braid; on tubular braiders with a large number of carriers the formers are as a rule electrically monitored, with a cut out to stop the machine in case of a fault. The article dealing with the various types of braid (page 10) shows how flat braids were developed into striped or section braids, and further development led to lace. The machines have naturally kept pace with these developments.



13
Pair of horngears providing six slots to hold three spools for making a simple plait.



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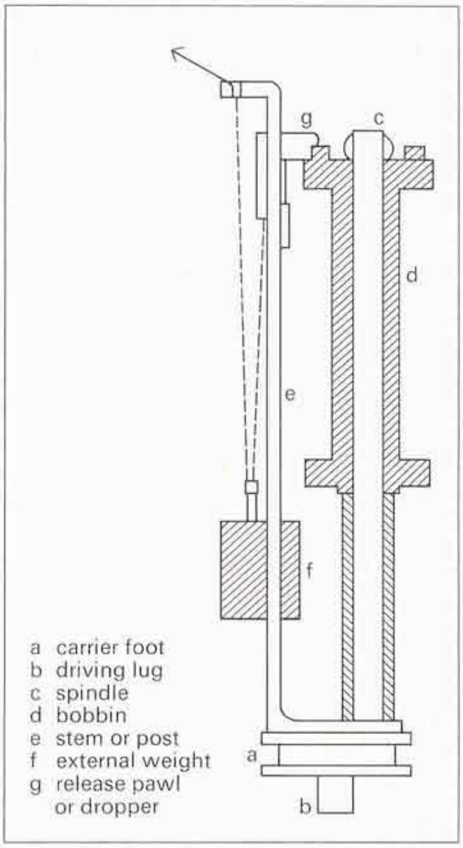
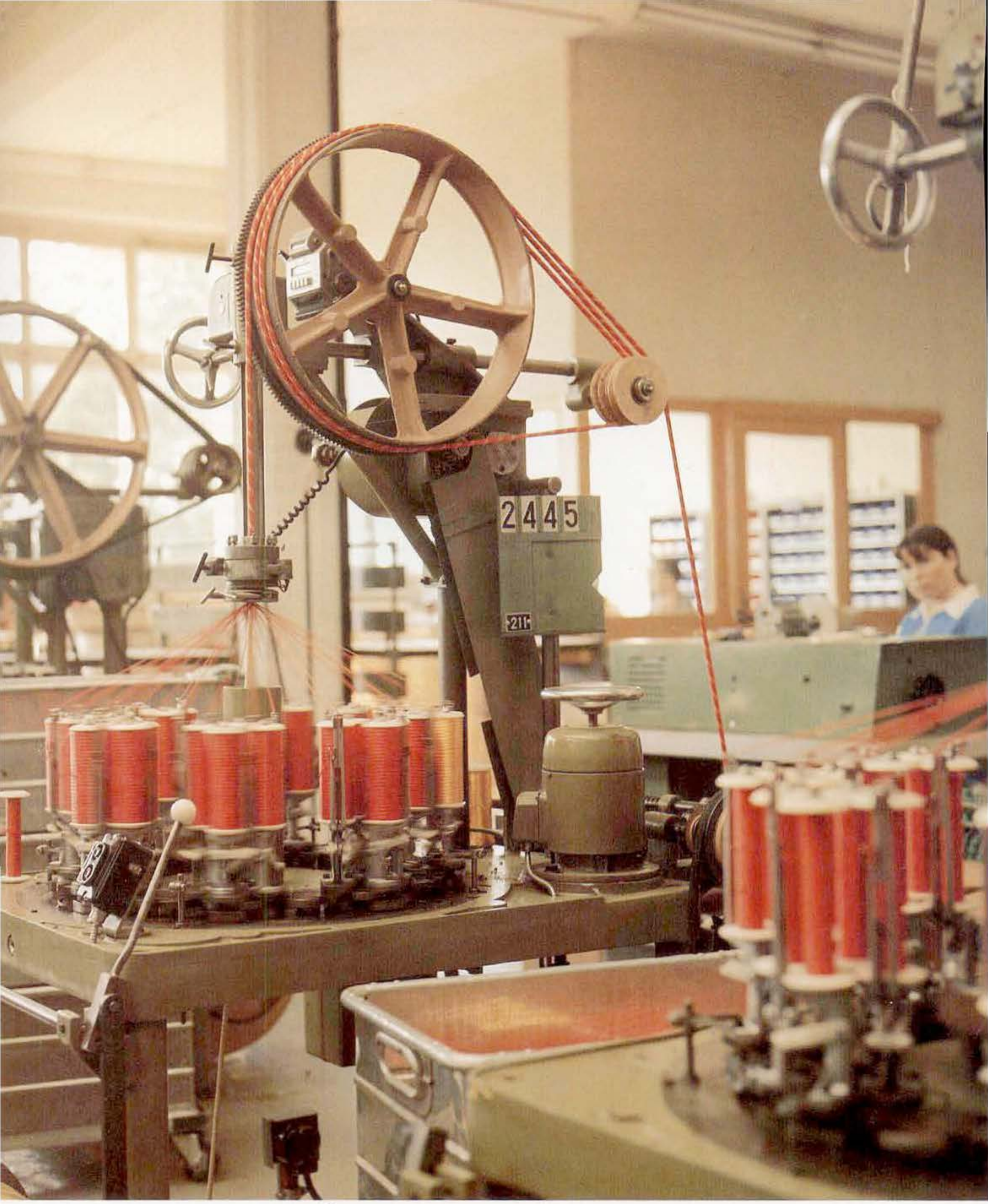
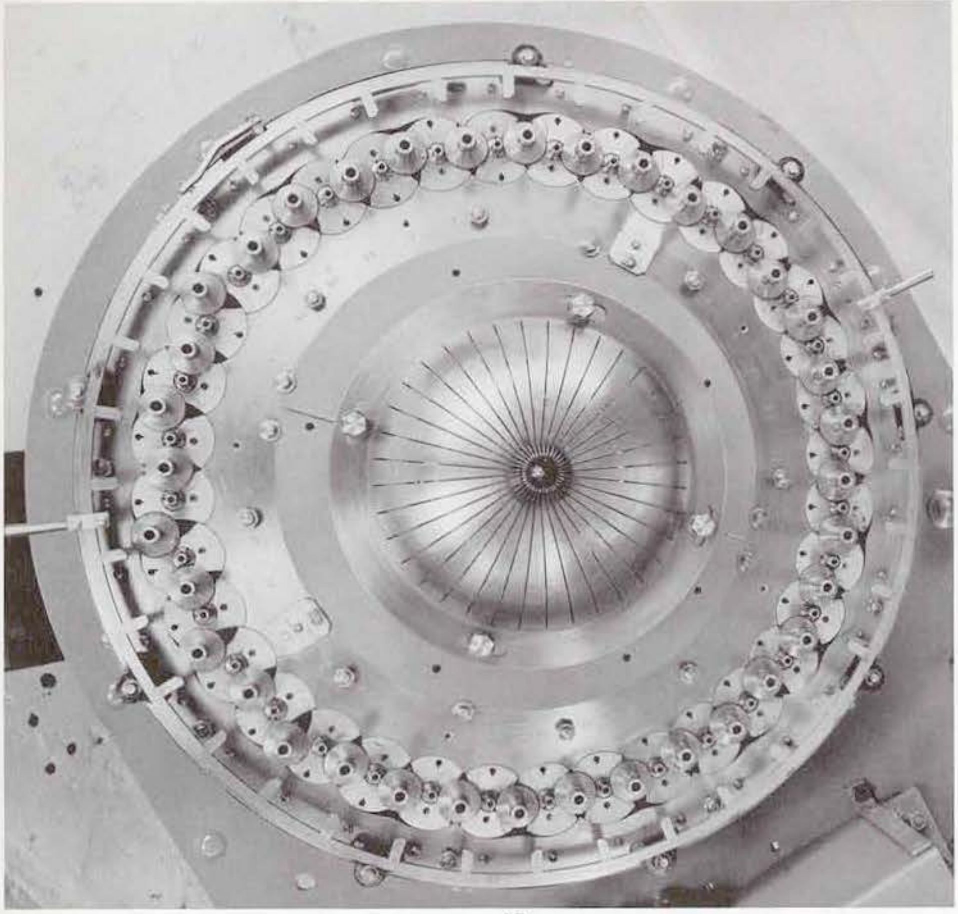
Simplified diagram of a flat braider.



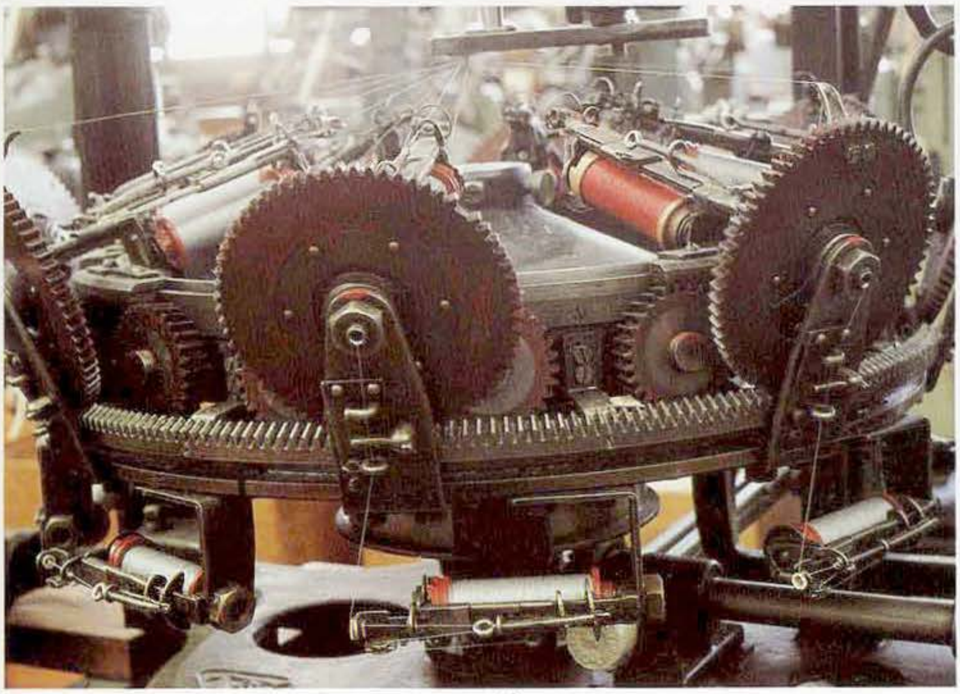
15
External drop weight carrier used on a slide plate Barmen type of braider.



16
Maypole braider.
(Courtesy of AROVA
Lenzburg AG/Switzerland;
photo by R. Zubler,
CIBA-GEIGY Limited)



17
Base plate of a lace machine. (Courtesy of Maschinenfabrik Emil Krenzler, Wuppertal Barmen, West Germany)



18
High speed rotary braider.

Figure 17 shows a typical lace machine. The movements of the carriers are controlled by a jacquard. All the gears mesh together, each rotating in the opposite direction to its neighbour. Clutches controlled by the jacquard can disengage carriers as the pattern requires; many different systems have been evolved. As one or more of the carriers may be out of action at any one time, the output of these machines is lower than that of ordinary braiders, where all the carriers are working all the time. Given a normal loading, carrier for carrier a braiding machine might produce, say, 20 metres an hour compared with 3–4 metres on a lace machine.

High speed rotary braiders

All the machines discussed so far have carriers travelling on a single plane. High speed rotary braiders work on a different principle, more akin to weaving in that there are separate warp and weft threads. Essentially the machine consists of an inner driving ring and a geared outer frame which provides the carrier tracking. Two sets of carriers (warp and weft) travel round circular orbits in opposite directions, and the threads are guided by various deflection systems to form the braid. These machines are very much faster than ordinary braiders, and are also usually quieter (Fig. 18).

Production rates

Economic working depends on several factors, one being output per unit of time. In braiding this is generally measured in stitches or picks per hour.

Plait styles are determined by the number of horngear slots and the size of carrier. The carriers on a maypole braider travel at speeds between 0.6 and 1 metre per second. These speeds apply to machines with a horngear pitch of 80–100 mm; for larger pitches they will of course be much slower.

High speed rotary braiders do not have horngears and output is measured by carrier circuits per minute. A typical speed would correspond to 3–3.5 metres per second on a maypole braider.

Increasing output

There are certain limitations on the productivity of braiding machines. For instance on a maypole braider, where the carriers keep changing direction, there are problems of inertia and stability. On high speed braiders the pay-off mechanism on the carrier may cause difficulties with yarn tension. Many attempts have been made to improve the productivity of the maypole braider. At the International Textile Machinery Exhibition (ITMA) in Paris in 1971 the German firm of Herzog demonstrated a braiding machine with a new carrier system. The first machines of this type had horngear pitches of 100 mm. The package size was increased from 260 to 485 m^3 and the gear speed from 240 to 350 rpm.

In West Germany too there is a new 32-carrier machine with a pitch of 1000 mm and 2-metre carriers, said to be capable of braiding braided strands of 20–40 mm diameter. Machines on this scale and even larger, built by Mackie of Belfast, Northern Ireland, have been used for many years for braiding tanker hawsers up to 150 mm in diameter. Among high speed braiders similar developments have been taking place, such as the high capacity Karg machine in the USA which is in the final stages of testing.

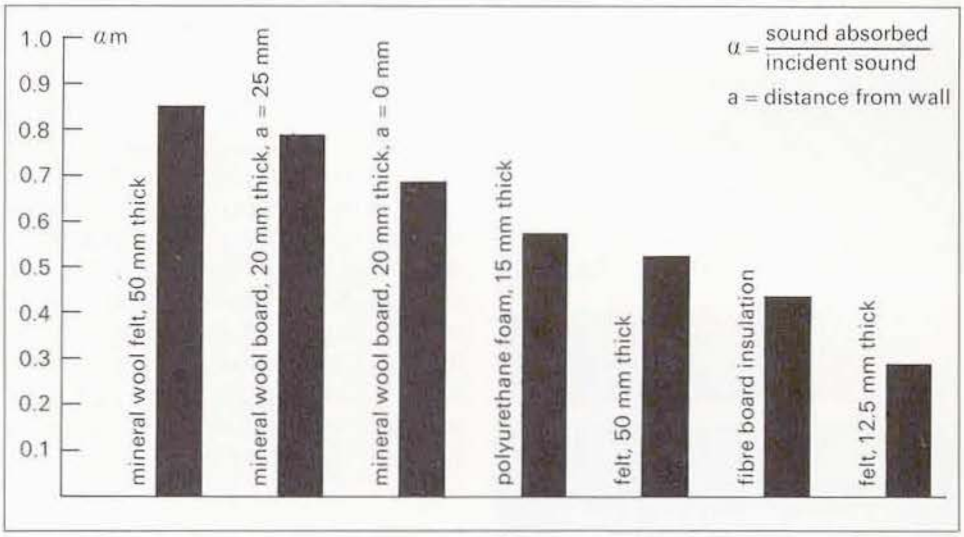
Noise abatement

Deafness due to industrial noise is recognised in many countries as an occupational disease. Machine manufacturers may therefore well give some thought to ways of reducing noise levels. In West Germany's official regulations for accident prevention, an appendix dealing with noise gives a list of machines considered by the trade association to exceed the statutory noise level of 90 decibels (dBA) permitted at the place of work. Braiders figure on this list along with pneumatic drills and riveters.

Sound-proofing is one way of reducing noise. Experiments with 32-carrier braiders fitted with internally sound-proofed metal hoods gave a noise level of 85.3 decibels with the access doors open, reducing to 82.2 decibels with the doors closed. The sound-proofing made the machines rather difficult to operate, and for that reason it has not proved successful.

A method which has proved more effective is to replace metal parts with plastics. Machines with moulded plastics (nylon/acetal) horngears and carriers such as the J. B. Hyde Pickmaster have been in successful operation for the past three years and have proved quieter than the older machines (85 decibels compared with 95).

Besides these aspects which are the concern of the machine manufacturer, there are other things which can be done to stop noise or lessen its effects. Figure 19 shows the mean sound absorption levels of various materials. Absorbency depends on the thickness as well as the type of material, and on distance from a wall: ordinary concrete walls reflect sound waves more effectively than padded walls. And of course personnel must be properly instructed: ear plugs and muffs and other preventatives are useless if they are not worn.



19
Sound absorbency of various materials.

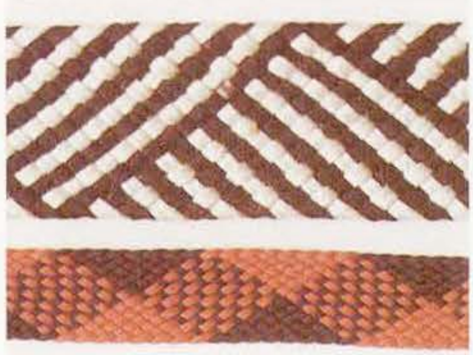
Illustrations are the author's unless otherwise attributed.

Machine braids

By W. Weber-Partenheimer

20
Russia or soutache braids.

21
President braids.



22
Flat braids.

23
Ricrac.

In braiding terminology braid, as distinct from braided cord, is a narrow fabric greater in width than in diameter. Braids are made in a wide variety of styles which differ according to the method of construction. This article deals mainly with the types of braid used in the trimmings industry.

Russia braid

Russia or soutache braid is a simple two-rib braid used for trimmings and embroidery. It is made on a machine with two horngears, each having not less than three slots. Various carrier combinations and colours can be used to produce a wide range of styles and patterns (Fig. 20).

President braid

President braids are three-rib braids, and thus require at least three horngears. The middle rib is often reinforced with a core yarn. Again there is a wide choice of styles which are used for uniforms, dress trimmings and embroidery; figure 21 shows a few popular examples.

Flat braid

Flat braids are a more elaborate version of these simple types. The number of horngears can be varied at will, and of course the more gears the wider the braid. The threads in the finished braid run diagonally from edge to edge, and special pattern effects can be produced by using different combinations of full and empty slots, with different yarns of different colours (Fig. 22).

Ricrac

Ricrac (looped edge or wave braid is made by using different carrie weights to vary the thread tension o individual carriers. Figure 23 show some examples used for trimmings If the two end plates of the braide are bored through the axis, war threads can be introduced; these ar not plaited in, but simply form par of the composition (Fig. 24).

The use of multiple rubber warp gives the braid considerable elasticity. A finger or a spiral spring ca be fitted to the terminal gears on th plane of the yarn path to the braidin point (Fig. 25) to produce loops o picots. A knife-edge finger will cu the loops to form a fringe (Fig. 26)

Tubular braid and cord

Tubular braid and braided cords ar made, as described in the previou article, on machines with carrie tracking which completes the circl round the braiding point (Fig. 27) The threads meet at the centre an interlace in a spiral. Tubular braider have an even number of carriers whereas flat braiders have an uneve number. A small number of gears wil produce a solid cord, while 24 gear and upwards will form a tubula braid which is hollow (Fig. 28); cor threads may be inserted to form core braid. This kind of braidin machine is commonly used for th coverings of electric wiring and hig pressure hoses.

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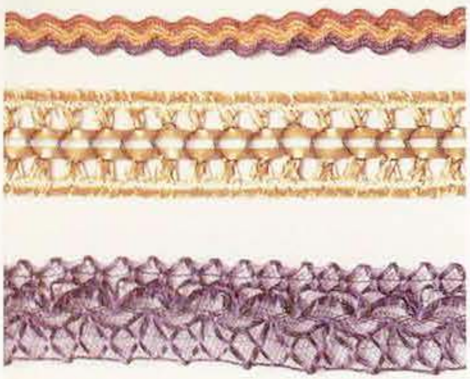
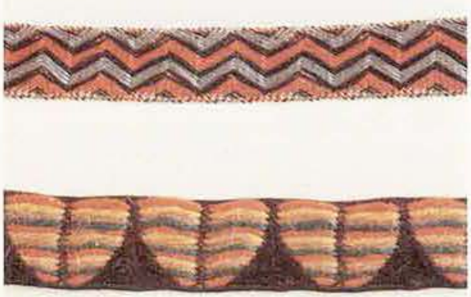
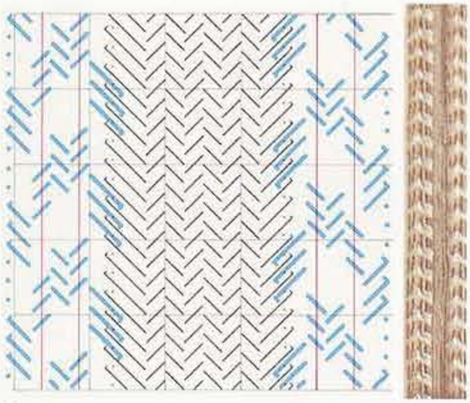


31
Section braids.

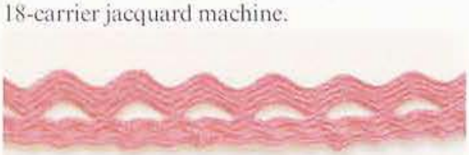


32
Jacquard braids.



33
Partial braid effects:
finished braid and pattern.

34
Braid lace made on an
18-carrier jacquard machine.



tachments on the braiding machine, such as automatic switch points for guiding the carriers, and so on. If however the pattern is elaborate enough to require a complex interchange of carriers, a jacquard is necessary. In that case two carrier tracks run parallel, like the up and down lines of a railway, and the carriers can be switched from one to the other by the jacquard. Figure 32 shows some examples of jacquard braiding. Usually a ground braid is formed on one track and a pattern is put on it by switching carriers from track to track as required. The machine can be set up to give a complete interchange of all the carriers on both tracks.

Buttonhole braid

Two braids are joined and run together, and the jacquard is set to split them at intervals and then rejoin them, thus forming buttonholes. The length of the hole and the distance from one to the next can of course be regulated.

Partial braiding

A section braiding machine can be set up to run with a certain number of spindles "missing" in each strip or section, so that the threads of each section plait intermittently with each other, thus creating a partial braid effect as shown in figure 33. The gaps in the braid are formed by this "dead spindle" patterning: the threads of each section plait only with each other. Where the carriers of one section join with those of another, the threads from the two sections are looped together, not plaited, and the result is a pattern like that in figure 34, which can be produced on an 18-carrier jacquard braid machine.

These machines were originally built to supersede hand lace making, and the formation of jacquard braid is the same as that of hand made lace. A jacquard controls the movements of the spindles individually on the different sections of the machine.

Braid lace

Machines with three or more spindles to each track are a form of braider, and the types of lace described above are to all intents and purposes braids. True lace machines have only two spindles, or more often nowadays one, to each horngear. Two threads of course cannot be plaited, but only twisted together. Lace is formed only when the steering mechanism (the jacquard) is set to move the carriers part or all of the way across so as to join up the separate partial braids.

One-thread lace

Fine lace can be made in a variety of patterns on a one-thread lace machine. As the name implies, the machine has only one spindle to each horngear. The spindles work in groups of four, corresponding to the four bobbins in hand made bobbin or pillow lace. The jacquard card corresponds to the lace worker's draft design on the point paper. Thus one machine with 44 spindles would be the equivalent of eleven lace workers sitting round a table doing their crossing and twisting in time together. Figure 35 shows a lace design, the design pricked out on the point paper and the finished lace.

mpty, one slot full (known as "full ccupation"). A sequence of two mpty, two full ("half occupation") ives a diamond braid or basket eave, with a stronger structure, in hich the threads cross two over two Fig. 29). This is what happens in aypole dancing. There are of course ther variations which are not so ommon.

Braided net

raided net is a form of tubular braid r cord. Only one carrier track is used nstead of the normal double trackng, and the threads are crossed and wisted to form a structure similar to ire netting.

Edge braid

dge braid, as the name suggests, is nade by joining a tubular braid to ne edge of a flat braid. This is done y combining round and flat braid racks with a common terminal hornear, as shown in figure 30. Core hreads are sometimes inserted in the ıbular edging.

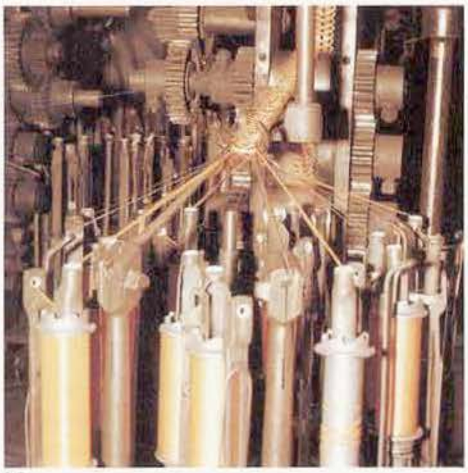
Section braid

ection braid is formed by combining wo or more flat braid tracks, again ith a common terminal horngear. t this terminal point the threads of ne set of carriers interloop with the hreads of the other set, thus in effect naking a wide braid out of two or nore narrower strips or sections, hich may be of different colours or atterns (Fig. 31).

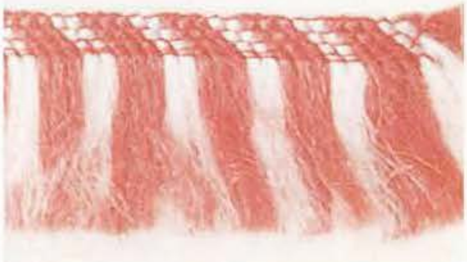
Jacquard braid

Iost of the braids described so far an be produced with only minor at-

24
A braiding machine threaded with warp threads.

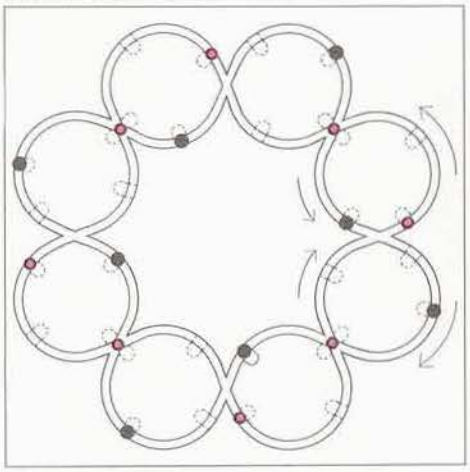


25
Fingers for holding out the braid at the braiding point.

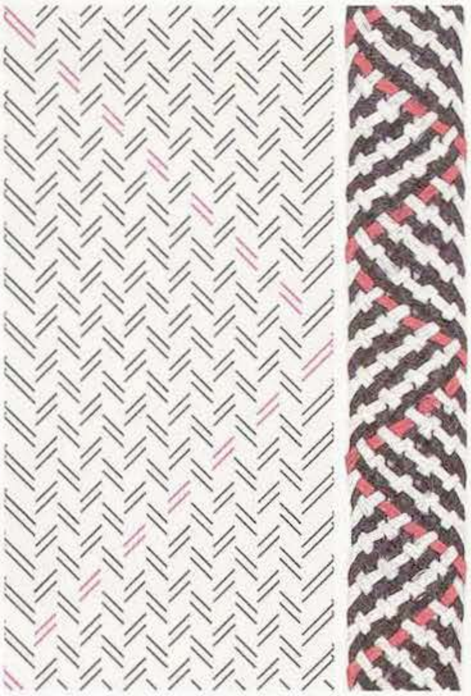


26
Fringed braid.

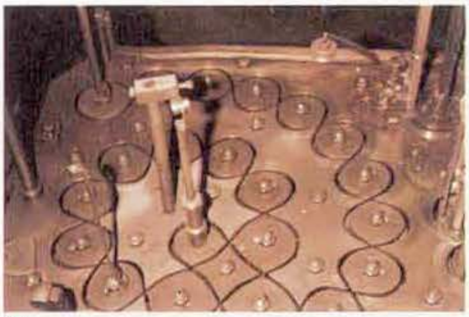
27
Tubular braider carrier track.



28
Circular cords.



29
Diamond braid (two over two): finished braid and pattern.



30
Carrier track for edge braiding.

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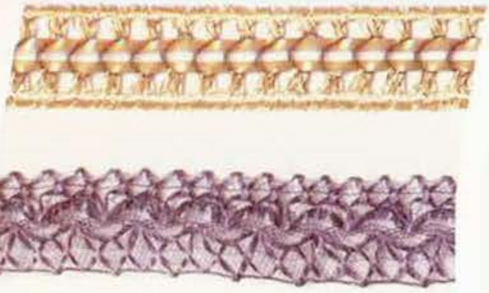

31
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2
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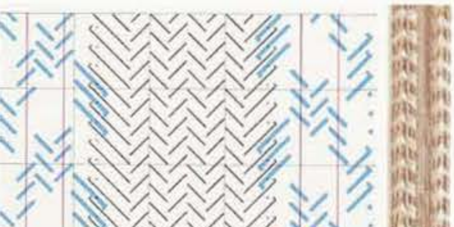

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Machines with three or more spindles to each track are a form of braider, and the types of lace described above are to all intents and purposes braids. True lace machines have only two spindles, or more often nowadays one, to each horngear. Two threads of course cannot be plaited, but only twisted together. Lace is formed only when the steering mechanism (the jacquard) is set to move the carriers part or all of the way across so as to join up the separate partial braids.

One-thread lace

Fine lace can be made in a variety of patterns on a one-thread lace machine. As the name implies, the machine has only one spindle to each horngear. The spindles work in groups of four, corresponding to the four bobbins in hand made bobbin or pillow lace. The jacquard card corresponds to the lace worker's draft design on the point paper. Thus one machine with 44 spindles would be the equivalent of eleven lace workers sitting round a table doing their crossing and twisting in time together. Figure 35 shows a lace design, the design pricked out on the point paper, and the finished lace.

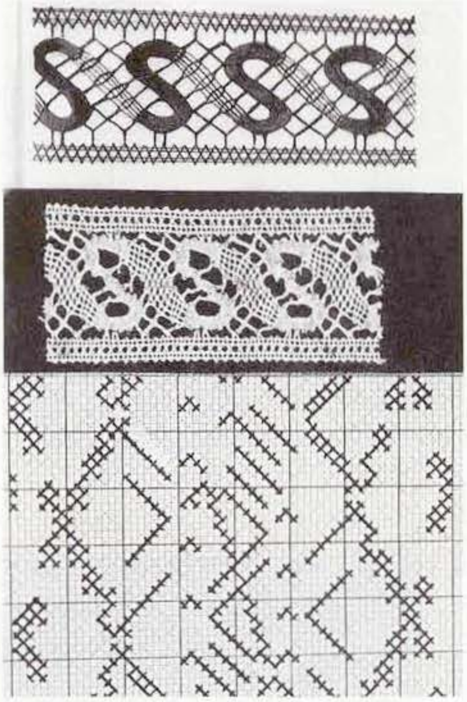
The leaves, dots, rays and other traditional motifs of hand made lace are all used in machine lace (Fig. 36), and a modern one-thread lace machine can reproduce any repeating pattern. From time to time new motifs have made their appearance, and these when worked in the new synthetic fibres have completely altered the character of machine made lace: the newer styles are in keeping with contemporary taste and fashion and are also economical to produce, so that lace is now being used again where once it would have been too expensive.

Circular knitted cords

Flat and tubular braids have their counterparts in knitting. A circular knitting machine with a very small cylinder can make tubular knitted cords which are hard to tell from the braided variety; the difference is in the loop construction of the knitted cord. The machine is in fact a type of crochet machine; it has latch needles and works on the weft knit principle, using a single yarn. Standard machines have from three to 18 needles. The form and structure of the finished cord depend on the needle count and stitch density. The loop formation gives the cord a relatively high stretch, which can be reduced by inserting core threads.

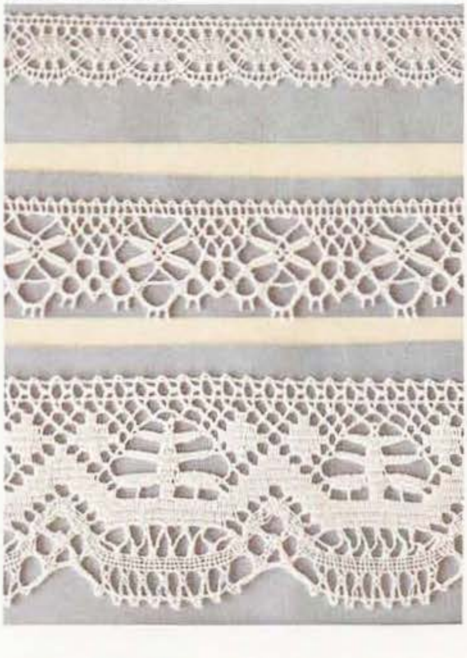
Crochet knitting machines

Crochet knitting machines work on the warp knit principle. The needles move horizontally, at right angles to the thread guides, and the distinguishing feature of the structure is that the stitches are continuous, either in ones or in groups, and are bound in with the weft threads running across at right angles or diagonally.



35
Three stages in lace making: draft design (top), point paper (bottom), and finished lace.

36
Traditional motifs on machine made cotton lace.



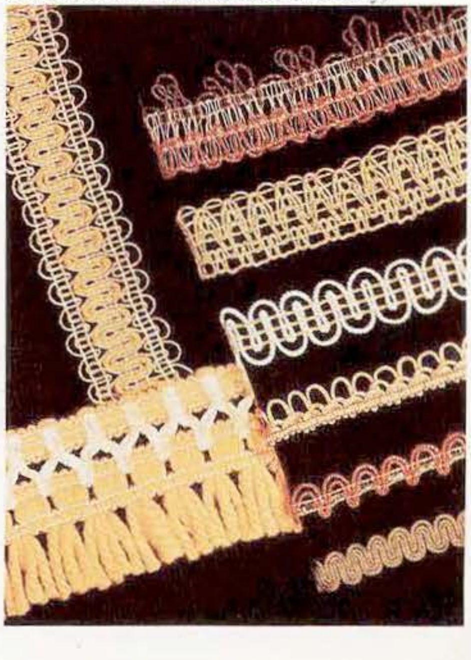
Circular cord can be used on these machines as well as ordinary yarn, and the choice of patterning is very wide.

Raschel machines

Raschel knitting machines also work on the warp knit principle. There are specially built machines for making narrow fabrics and trimmings of all widths up to 100 cm. These special trimming machines have spring beard needles instead of the latch needles normally used on raschel machines. The patterning range is wide since the pattern bars are threaded up individually and their movements are controlled as the pattern dictates. Various attachments can be used to extend the pattern range. Figure 37 shows some examples of narrow fabrics and trimmings produced on raschel machines.

English version of this and the preceding article by B.H. de C. Ireland, Manchester, with gratefully acknowledged help and advice from Peter Davenport of P. Davenport Limited, Macclesfield; Michael Hyde and Bryan Davies of J.B. Hyde and Co. Ltd, Altrincham; and H. von Achten of Oldham Elastic Manufacturing Co. Ltd, Oldham.

37
Lace made on raschel machines.
(Courtesy of Karl Meyer
GmbH, Obersthausen, West Germany)



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nless otherwise attributed.

Patents and skills

By W. Weber-Partenheimer

Precursors

The Englishman *Thomas Walford* is generally named in the literature as the inventor of the braiding machine, on the basis of his patent number 638, submitted in 1748, for "an engine or machine for the laying or intermixing of threads, cord or thongs of different kinds, commonly called platting". The drawings submitted with the patent application are not very clear.

Johann Heinrich Bockmühl, born in 1738 in Kemna near Barmen and later to be become a manufacturer, demonstrated his own braiding machine design to his sovereign during the latter's visit to Barmen in 1767. Although there are no pictures of Bockmühl's braiding machine in existence, a Frenchman who spent some time in Wuppertal gave in his enthusiastic account of his travels a detailed description of a lace or strap machine. The first pictures of braiding machines, together with a description, appeared in the *Choreographie* of Schwelm which was published by Pastor Müller in 1789.

Laces or straps were also listed in a statistical report of the towns of Wuppertal-Elberfeld in 1720. The craft of braiding was probably introduced by the Dutch *Passementenmaker* who left their homeland at the beginning of the 17th Century because of political and religious unrest and found a new home in Wuppertal.

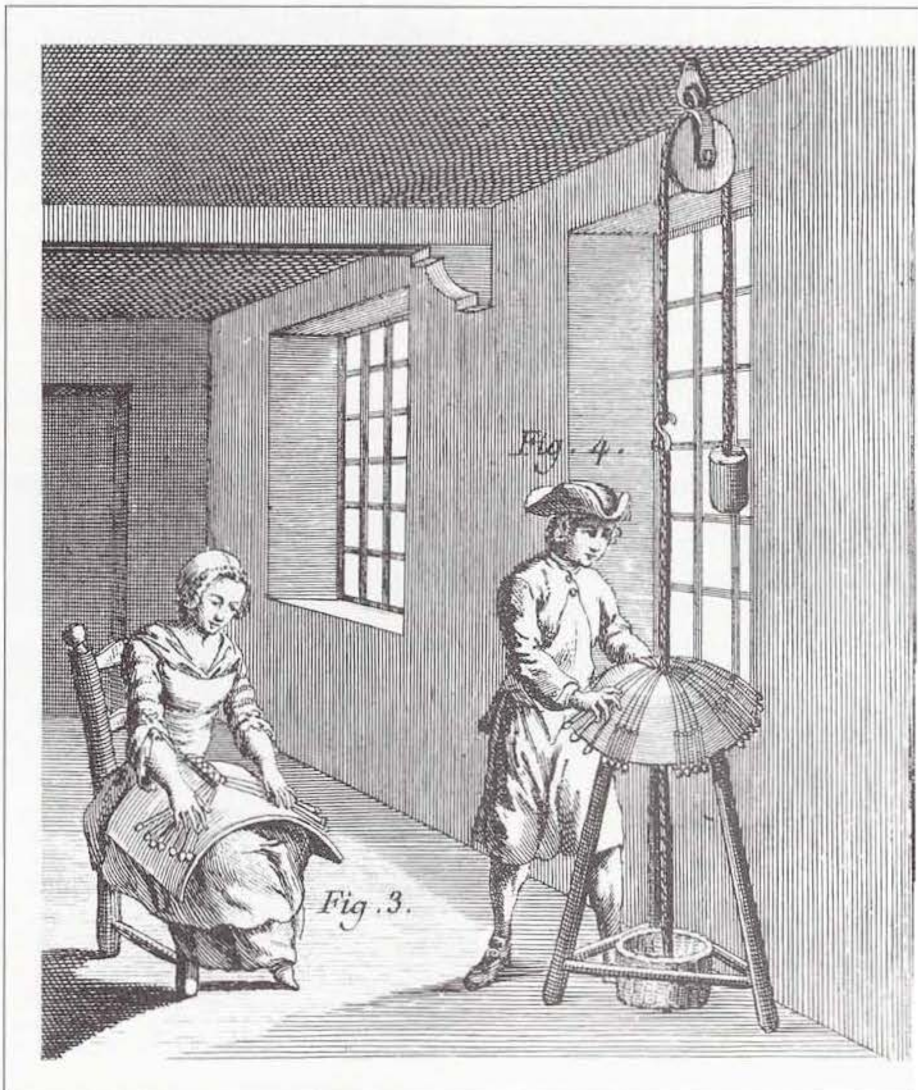
These "passementiers" used certain auxiliary devices to facilitate their work. Perhaps the most used were conical blocks of wood, on which the braided material was wound. Judging from the various published finds of these, they must have been in general use in Switzerland (Disentis), on the island of Föhr, in Friesland and in many other places.

A further device is described in *Prechtl's Technical Encyclopaedia,* Stuttgart, 1843. According to this description, a segment of a hollow wooden cylinder is used in braiding. This drum is reproduced in the encyclopaedia of Diderot and d'Alembert (Fig. 38). The second person in the picture (right) is using a device for braiding a sheath around a heavy core, similar to devices used in Japan (p. 29). The museum of local history and culture of the town of Lenzburg possesses one of these machines which was used primarily for making watch-guards out of horsehair.

The development of braiding n chines in Wuppertal naturally caus considerable excitement. It is certa that Bockmühl was not the only c to build such machines. These pro ably also found their way to otl countries, by various means, a were copied there. France in part ular, together with Wuppertal, co tributed much to the further dev opment of braiding machines.

Around 1780, the French mar

38
Segment of a wooden cylinder (Fig. 3) and special device (Fig. 4) for braiding round cores. From the encyclopaedia of Diderot and d'Alembert.
Photo: H. Sager, Basle.



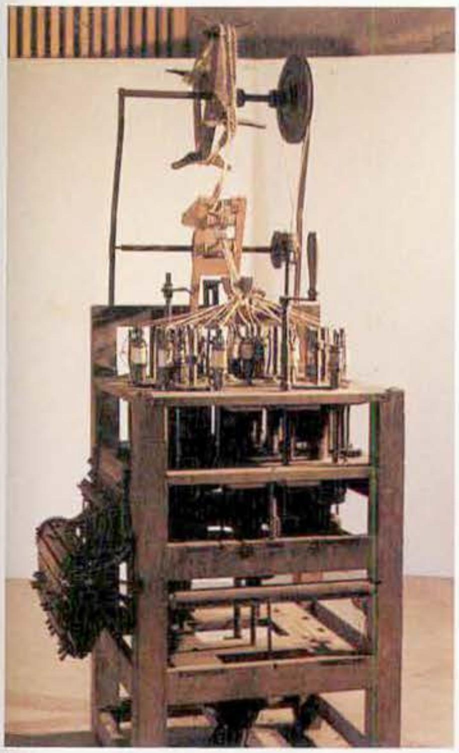
facturer and machine-builder *E. Perrault*, a native of Normandy, visited Wuppertal to study the German braiding machines. The records show that he purchased one of these. He then copied this machine on his return to France, adding many improvements. The Perrault braiding machine came into wide use in the decades that followed, particularly in the region of St. Etienne (Lyons), where occasional machines were still in use up to a few years ago.

The Perrault machine also became known in the canton of Aargau, particularly after 1840. Some credit for this must be given to the firm of Diebold in Baden (Switzerland), who built these machines for the Argovian braiding industry. A particularly useful device was developed by the firm of Kündig in Arth. They built a jacquard-like control mechanism – the so-called "Ratière" apparatus – into braiding machines (Fig. 39), with the aid of which the production of patterns was greatly simplified.

Constructions of special interest

It would exceed the terms of reference of this paper to discuss in detail all the manifold patents and constructions that followed, so that I have restricted my comments to a few outstanding examples:

For example, in 1823 the Englishman *John Heathcoat* proposed a machine (BP 4867) with a concave track plate and spools inclined towards the braiding point (Fig. 40), to solve the problem of the length differences on braiding machines. This idea of building machines with the spools inclined towards the braiding point has turned up time and time again. In fact, the last patent on a braiding machine with a concave track plate was taken out by a German firm in 1955.

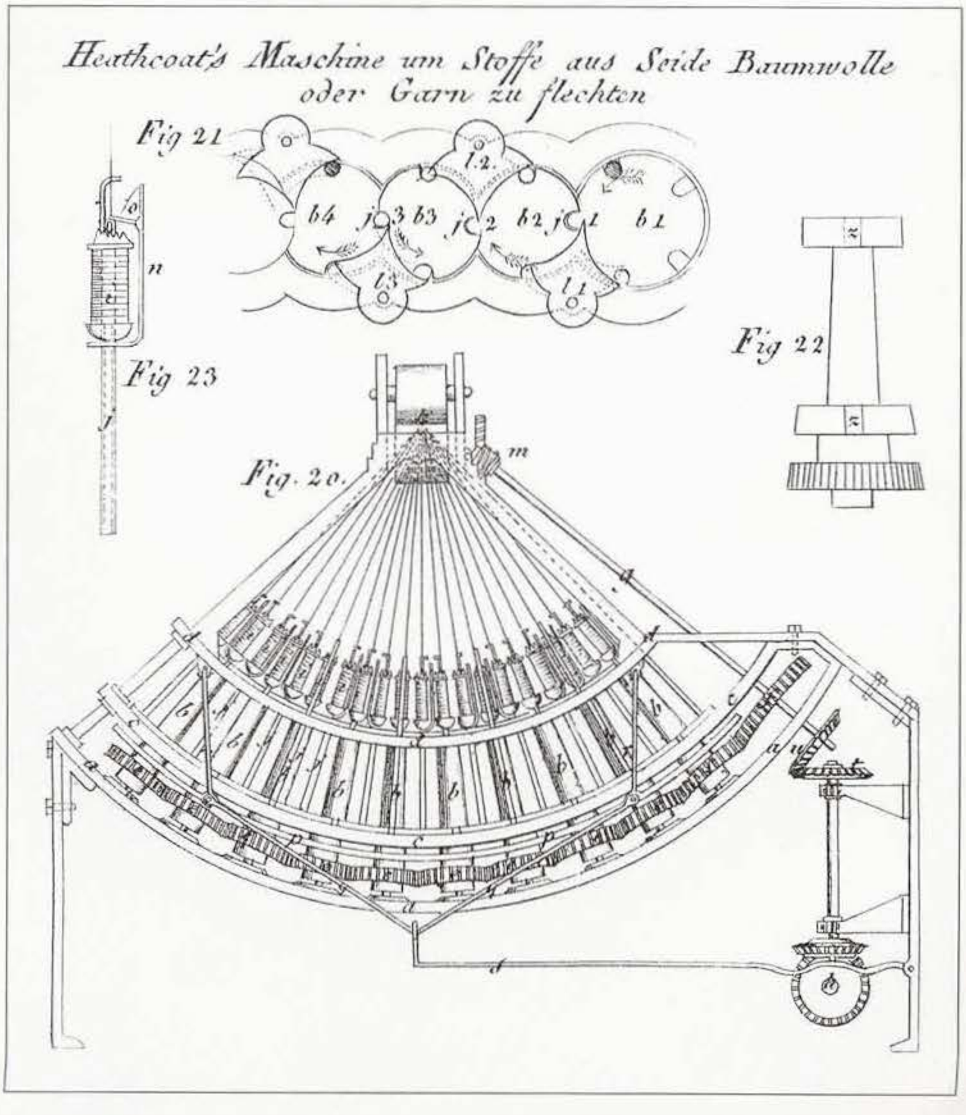


39

Braiding machine following the system of the firm Kündig in Arth, with its Ratière device, a jacquard-like control.

40

Braiding machine with a concave guide plate according to the patent of John Heathcoat, 1823.
From the *Polytechnisches Journal* of Dr. J. G. Dingler, vol. 19, Stuttgart, 1826.


Heathcoat's Maschine um Stoffe aus Seide Baumwolle oder Garn zu flechten
Fig 21
Fig 22
Fig 23
Fig. 20.
b4
b3
b2
b1
n
m

The first machine for manufacturing partial braids, the link between braiding and bobbin lace making, was designed in 1840 by *Ch. Nickel* and comprised three heald braiding machines with 5, 9 and 13 spools, one working inside the other (BP 8537).

Bobbin lace making by hand had long been popular in the Erzgebirge in Saxony (Barbara Uttmann), so that it was by no means surprising when in 1860 *Louis Hohl* from Annaberg submitted an application for a patent on a bobbin lace machine developed from the braiding machines already in existence. His plans were examined at the Dresden College of Technology.

Developing the idea of mechanical production of bobbin lace, in 1872 the Frenchman *Eugen Malhère* was granted his first patent (FP 93970) on an improved system of bobbin control (introduction of the Jacquard device), while in Wuppertal it was the firms of Hedtmann, Reising and Büsche who were the first to contribute to the mechanical production of lace. *Hedtmann* published details of a combined braiding and bobbin lace machine (GP 1567) in 1877, and in 1880 *Reising* took parts of the carriers out of the track so that they were temporarily at rest (GP 14253). In the same year *Büsche* introduced separation of the track plate and the cogwheel that drives it, so that the spools could be kept idle indefinitely (GP 17500), a possibility not offered by Reising's system of adjacent plates.

The special requirements of the engineering industry made it necessary to produce braids that were lubricated (e.g. for packing and sealing materials). The first patent for a machine of this kind was granted to the Englishman *F. James* (BP 2045/1871). In order to avoid soiling of the spool carriers, which is almost inevitable when braiding cords impregnated with graphite or talc, machines were built with overhead (hanging) spools (GP 26282/1893, Bolze & Co., Braunschweig). Since that time, braiding machines with overhead spools have been and still are the machines of preference for braiding packing (Fig. 41).

41
Packing cord braider with overhead (hanging) spools.
Photo: Merkel, Hamburg (GFR).

Another construction that deviates from the normal working pattern of a machine for tubular braids is that designed by Luckenhaus & Quambusch (GP 70308/1892). In order to produce round cords, the hollow centre which is formed on the conventional machine must be filled with filler threads (core). If this is omitted we obtain a hollow tubular braid. According to the above invention, this situation is avoided by an interlocking of inner and outer threads: a central, inner track is enclosed in an outer track. Large winged discs of the inner track provide the connexion with the outer track. The spool carriers run one behind the other and thus provide a connexion between spools of the outer and those of the inner pathway.

In patent No. 60336/1891, granted to the Lusebrink Bros of Barmen, the take-up reel for the finished braid is situated above the machine. By means of an appropriate rod arrangement, the take-up reel, in addition to turning in the direction necessary to wind on the braid, is also turned at right-angles to the axis. In this way, the finished braid is twisted during its long passage through the hollow shaft, to form a spiral cord braid.

The braiding industry, as a supplier of fashion accessories, is and always has been very dependent on fashion trends. Some years very wide braids are in demand and other years very narrow braids. To help overcome the production problems raised by these requirements, in 1908 (CH P 77360) the Swiss inventors *Steinmann* and *Pfrunder* proposed a machine without a fixed track: The winged spool plates, fitted with eccentric pins, could be screwed on the grid-like base plate in any order, as required.

As early as 1866, *von Veerkamp* and *Leopold* (BP 945) proposed a machine with spools arranged in two decks, one above the other, with the aim of improving performance. These so-called rapid runners were subsequently developed to a high degree of perfection, in particular by *Wardwell* in America and *Tobler* and *Horn* in Germany. By means of various devices (patented) Horn developed his machines to the point where, in addition to the high performance level, a certain degree of pattern variation was also possible.

Finally I should like to mention two patents which show great inventiveness, though the actual machines were never built:

On all braiding machines the material to be braided is drawn off spools and the actual braid is formed by appropriate movement of the spool carriers. Deviating from this basic idea, on the machine proposed by N. Fraser (Scot. Pat. 22064/1881) the whole thread system – i.e. the finished braid – is moved alternately over and under the threads to be braided which remain in a fixed position. Curved braiding arms move about horizontal axes and carry the braiding material to the centre of the machine. Braiding is carried out as follows: guide rollers carry the braid into the take-up device where it is moved about a vertical axis, passing alternately over and under the swinging braiding arms.

The second patent is aimed at reducing noise: Carl W. Schmidt, Elberfeld, proposed a braiding machine (GP 720/1912) in which the spool carriers would be moved electromagnetically and not by the conventional system of cogwheels. According to this patent, the track plate should consist of a thin, continuous sheet of insulating material laid directly on the magnet plate. The spools would be moved by appropriate switching of the magnets.

Straw plaiting in Aargau

Straw plaiting in Switzerland has a long history. As early as 1593 the records show that the Zurich City Council confirmed the right of the "barbers" of that city to manufacture plaited straw hats. The guild had complained in a petition that the local craft would be damaged by wholesale selling by foreign dealers.

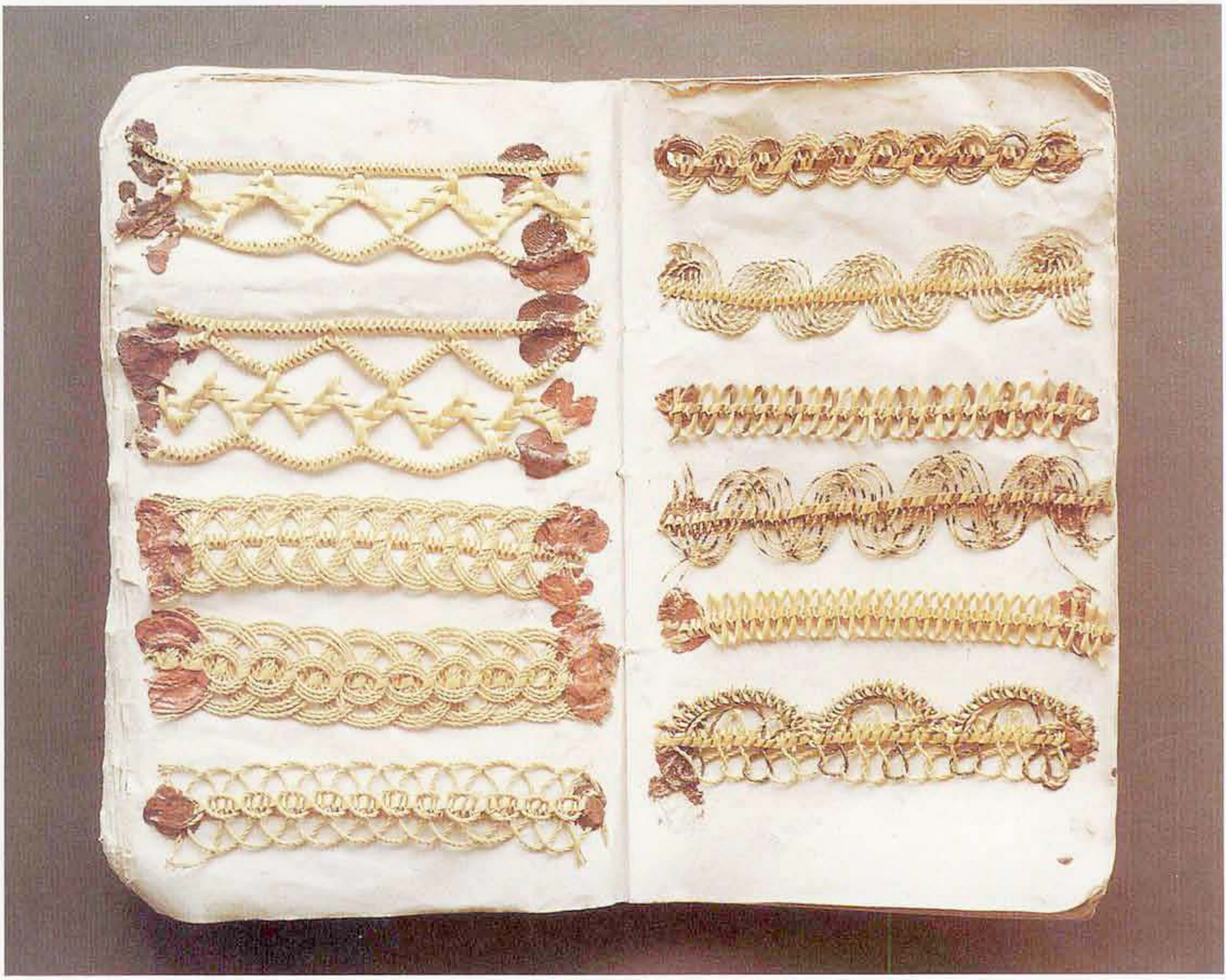
A number of dealers in plaited straw are mentioned by name in the chronicles of the town of Lenzburg for 1606. It is also revealed in the rent-roll of the monastery of Hermetschwil near Bremgarten for 1643–44 that the monastery often received straw hats as a form of rent from its tenants. In 1743, two citizens of Wohlen complained to the "Bailiff" on behalf of the "dealers in plaited straw" that a large number of plaiters were no longer adhering to the customary length conventions, and that by so doing they were cheating dealers and customers "in a most unseemly manner". It was also in Wohlen that the first trading company was founded by eight local dealers in 1783.

At that time straw plaiting was not at all organized, but was simply a family occupation carried out in the home, for the most part in winter (CIBA Review No.35). Following the founding of the canton Aargau straw plaiting in this area developed more and more into a genuine export industry, and several places became known for their specialities. The finished articles were bought from the plaiters by dealers.

For a long time Wohlen was the trading centre or exchange for the many plaited straw dealers, not only from the immediate locality but also from many adjacent areas such as the Fricktal, the Lake Valley of Aargau and Lucerne, Entlebuch and Nidwalden. In order to maintain a high quality of plaited straw articles, craft schools were set up in various places at the beginning of the 19th Century. Girls of any age were accepted while boys had to be under 14 years of age. According to the regulations, pupils were to work only in the daytime in summer and, in winter, they were to make their way home "in a quiet and seemly manner" by 11 p.m. at the latest.

Initially, straw plaiters in Aargau used only rye. This was a tough and readily worked material. Since, for plaiting, straws should be ideally as long and fine as possible, different methods of cultivation to those used in grain crop raising were employed. Prerequisites for obtaining good material were soil that was not too rich, only little fertilizer and fields protected from the wind. The land cultivated should afford only so much nutrient to cause the seed grain to throw up a shoot. Dense seeding ensured that the stalks would grow long and fine. The rye was cut long before the grain ripened, so that land used for growing plaiting straw did not supply any cereal crop.

However, the dark rye straw could not compete in the long term with products made from the lighter wheat straw, which were offered for sale from the canton Fribourg, from Belgium, England and Saxony. The foreign products were superior to local straw articles with regard to lustre, fineness and craftsmanship. In order to counter these setbacks, the pop-



42
Pattern book of a dealer in straw braids, 1865.

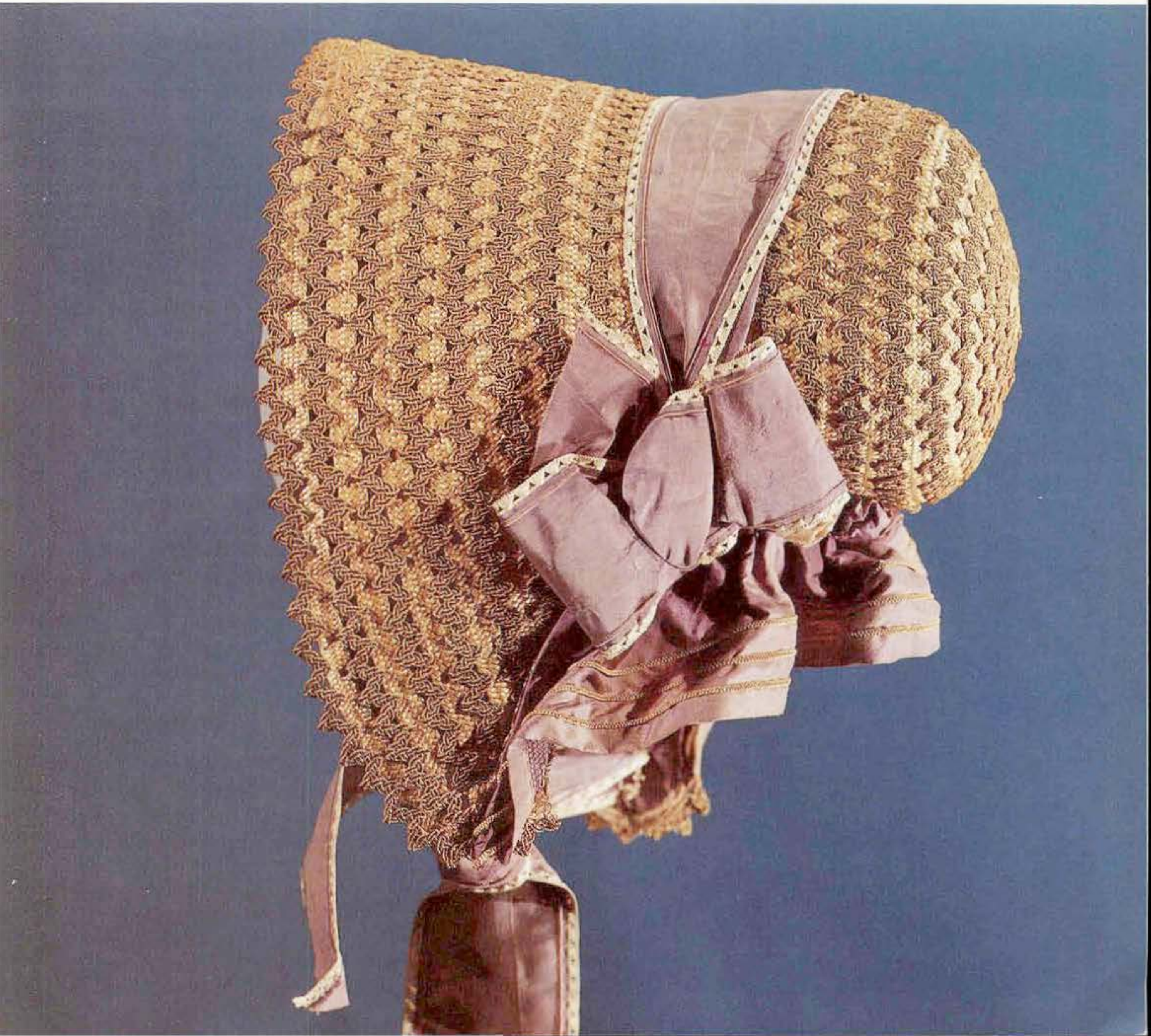
lation was formally called upon to romote the use of wheat straw intead of the traditional rye. The first traw dyeing centres were set up round 1830 and, somewhat later, aw materials other than straw began o be incorporated. Perhaps the most mportant of these were raffia, Maillа hemp, cotton, horsehair and rtificial silk.

ools used in the straw plaiting trade vere opener, scraper, grader, straw ress, "Schnürlirädli", fusion cutting levice, rasp, studded beater, hand pindle and, later, a trimmings loom.

uring the winter months the dried nd bleached straw was sorted in the rader, consisting of a wooden frame nd interchangeable screens of 5–8 lifferent sizes. The subsequent width f the plaited material depended on ow accurately the straws were sortd, to obtain lots of equal diameter. n order to obtain flat straws, these vere opened up with the aid of an pener. The pith could then be removed, using a scraper on a wooden surface. Depending on what they were to be used for, the straws could also be further divided with the aid of a splitting tool, to give several thin strips. The individual, opened or split straws were then wetted and drawn several times through a straw rasp, to make the strips supple and soft.

The short, narrow strips of straw were subsequently twisted on the "Schnürlirädli". This device, also known as a "Strohdrahträdli", was introduced into the Argovian straw plaiting industry around 1840. The tough and supple plaiting material produced in this way was used for the most varied types of article. It was used on the trimmings loom, as well as on the "Rädligeflechts-Rädli" where it was worked into open, netlike constructions. These wide bands of plaited material were then worked with straw bands, horsehair and other materials in a filet-like manner and, particularly with foreign materials, a quite unique effect was obtained.

There are numerous other working aids and plaiting tools designed by inventive dealers or plaiters, which could be listed. Among these were – sometimes remarkably simple – devices that enabled individual families or communities to occupy a kind of monopoly position, or working aids with which miniature works of art were produced in a large variety of forms, that could no longer be repeated today.



43
Poke bonnet of plaited straw, about 1880.
Photo: Cantonal Historical Collection, Schloss Lenzburg (CH).

Industrial and other braids

By W. Weber-Partenheimer

Ropes

A great advantage of braided ropes is the absence of spin on loading. If a twisted rope is loaded in an axial direction torsional strains are created due to the twist angle, and the rope tends to unwind itself. With a braided rope, however, these forces cancel each other out (Fig. 44). This effect means that for marine applications, for example, braided ropes will be given preference. Polypropylene is the most used material. It does not absorb water and has a specific gravity 20% lower than that of nylon. Its somewhat lower stability to U/V radiation is compensated for by using appropriate stabilizers (Fig. 45).

Packing cords

Unsuitable packing leads to leakages, frequent replacement and, consequently, unnecessary expense. For this reason the industry has developed a large selection of packing and seal types designed specifically for the application in which they are to be used. The base material used will depend on the medium requiring sealing and on the operating temperature, while the structure of the packing will depend on the speed at which mobile packed surfaces are moved.

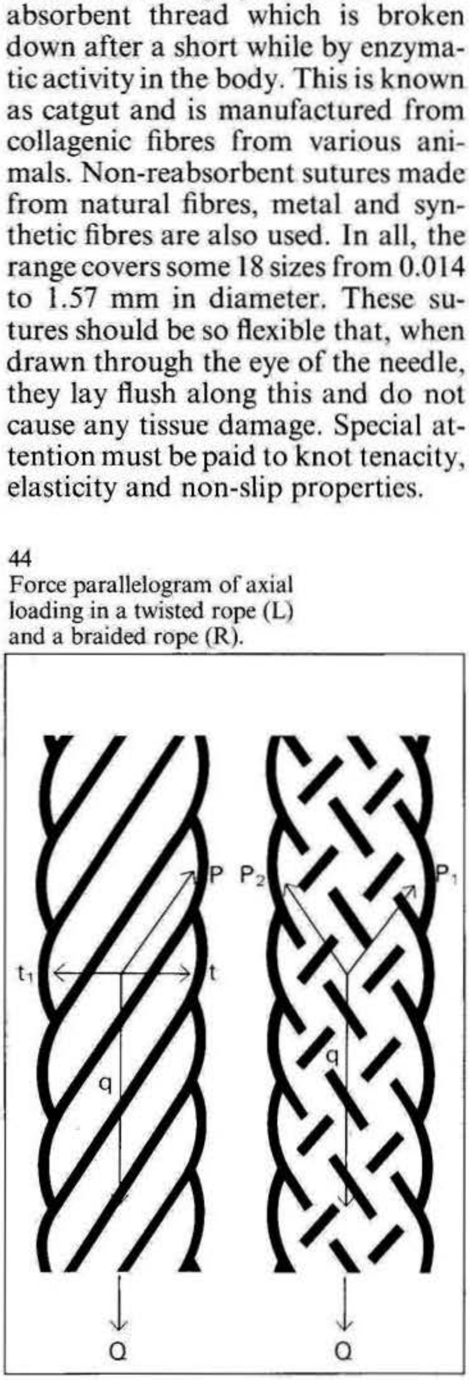
Cotton and ramie have proved satisfactory as base materials for packing of which only little is demanded. In the case of corrosive media and high temperatures it is generally asbestos packing which is used (CIBA-GEIGY Review 1972/2).

Among the synthetic fibres, polytetrafluorethylene fibres (Teflon) in particular have shown themselves to be universally applicable. Where good heat conductivity or abrasion resistance are required packing made from a combination of asbestos and Teflon is used.

On early steam engines a simple braided rope impregnated (before braiding) with oil sufficed. Later, tallow, mineral greases, graphite and other lubricants were added. Today polytetrafluorethylene dispersions are used for heavy duty packing. Impregnation of the packing is done to reduce friction between the packing and the working or slipping surface, to protect the packing material from chemical attack and to give it a certain degree of strength while promoting elasticity.

Surgical sutures

For closing wounds or tying off vessels modern surgery makes use of reabsorbent thread which is broken down after a short while by enzymatic activity in the body. This is known as catgut and is manufactured from collagenic fibres from various animals. Non-reabsorbent sutures made from natural fibres, metal and synthetic fibres are also used. In all, the range covers some 18 sizes from 0.014 to 1.57 mm in diameter. These sutures should be so flexible that, when drawn through the eye of the needle, they lay flush along this and do not cause any tissue damage. Special attention must be paid to knot tenacity, elasticity and non-slip properties.



44
Force parallelogram of axial loading in a twisted rope (L) and a braided rope (R).

Depending on the size of thread required, nylon and polyester yarns are used which have been braided on 8-, 12- or 16-spool machines. The exact relationship between the number of fibrils and the strength, and the effect of the number of braids per unit length and other factors on the stiffness and knot tenacity of the suture material has not yet been closely studied, so that successful manufacture still depends to a large extent on the experience and skill of the producer.

Double braids

Core-sheath braids contain a core which makes up more than 50% of the total weight. More exact specifications are not made. So, for example, a normal tubular braid with 16 to 24 elements may be braided round again in a special operation on 24- to 32-spool machines. Advantages of this procedure – in addition to the above-mentioned absence of torsional strains – are efficient use of the cross-section and good flexibility, even with large-diameter ropes.

Efficient use of material and space gives a high breaking strength, so that for identical breaking strength requirements double braids of smaller diameter can be used than would be necessary with ordinary tubular braids. Smaller diameters naturally mean lower weights. This argument was no doubt partially responsible for the selection of double braided cords for the brake parachute of the space capsule in the US Gemini programme (Fig. 46).

Drive cords

Power transmission on the high-speed machines of the Swiss watchmaking industry is achieved with the aid of cotton cords. Cotton has proved very resilient to the fluctuating bending stresses in this application. Since the cords have to be of uniform diameter over their full length, so that the instruments are not subjected to any jolts, these are braided in endless form. Depending on the desired diameter, several layers are braided one over the other. On completion, the cord is removed from the machine, which opens on a hinge (Fig. 47), and the threads of the outermost layer are sewn up or spliced in carefully by hand.

High-pressure hoses

The products of hose manufacture are divided into two groups according to the demands made on them:
- hoses with no core and
- high-pressure hoses.

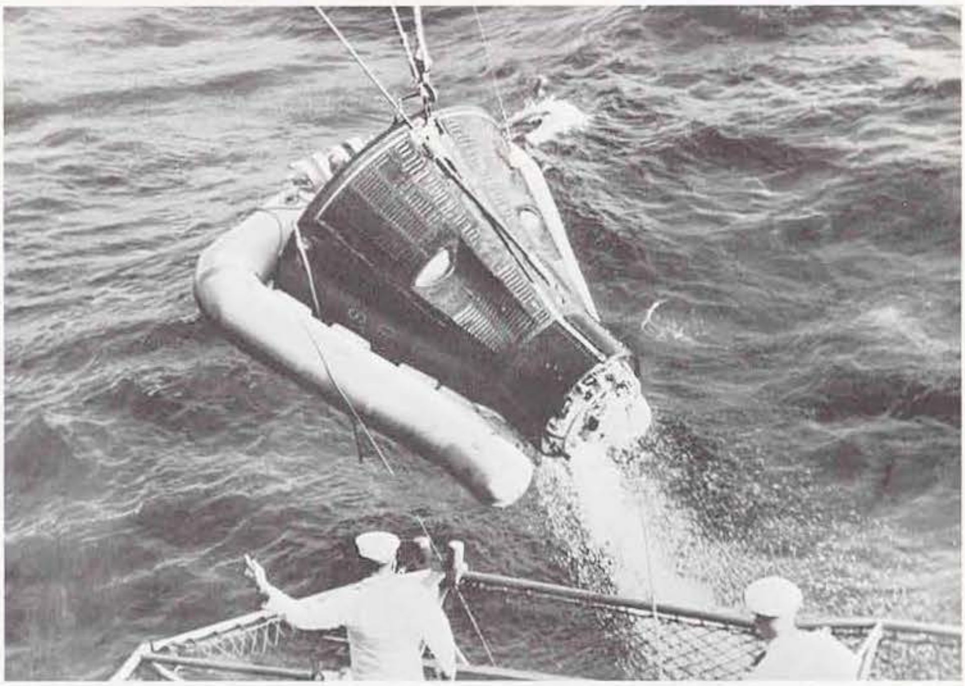
Hoses without cores are used at working pressures up to some 2 atmos. gauge. They are sprayed on the spraying machine and then vulcanized.

The unvulcanized tube can, however, also be used as a core for high-pressure hoses, the rubber quality used and the wall thickness depending on the intended end-use. The unvulcanized rubber core is drawn over a metal spike and the textile braided round it. On machines used for this kind of braiding the goods are generally drawn off horizontally, with a caterpillar chain, since the finished product must not be bent prior to vulcanizing. The braiding materials and machines used will depend on the required hose diameters and pressure specifications.

Mountaineering and sailing

An area where braided ropes are part and parcel of everyday activity is that of mountain climbing. Core-sheath ropes have become established on a worldwide scale in this area (Fig. 48). It is widely believed – and falsely – that in core-sheath ropes only the core performs an actual load-bearing function. In fact, core and sheath are so closely involved one with the other as a result of the structure of the rope that a separation of load-bearing functions is impossible. However, one special property that the sheath must possess is a very high resistance to abrasion. This is achieved amongst other things by using machines with

45
Braided ropes in polypropylene (monofil and split fibre) of 30 and 40 mm diameter.



46
After splashdown the Gemini 3 space capsule is winched aboard the aircraft carrier on a braided core-sheath rope.
Photo: Ringier Picture Services Ltd., Zurich (CH).

47
A finished drive cord is removed from the opened endless braid machine.

48
Core-sheath climbing ropes in fashionable colour combinations. Photo: AROVA Ltd., Lenzburg (CH).

49
Combined dyeing and thermo-fixing unit for ropes and cords. Photo: Feinwerktechnik Hans-U. Sohr Ltd., Sprendlingen (GFR).

a large number of spools, which gi
a firm but fine sheath structure.

In sailing, ropes are required wit
only little stretch capability. The
should also be as supple and as d
mensionally stable as possible:

- supple so that they run easily ov
  the blocks and lie comfortably i
  the hand when working;
- dimensionally stable so that the
  do not slip when belayed with pin

All these requirements are best m
with double braids.

Dyeing and impregnating

Nylon climbing ropes are made fro
brightly coloured yarns not only f
aesthetic reasons but also for reaso
of safety: when climbing on hig
mountains with a double rope,
helps if the ropes are of differe
colours. Furthermore, the colou
protect the rope from the harmf
U/V radiation which is stronger
great heights.

The use of luminous dyes has opene
up entirely new possibilities, eve
though the very high lightfastness r
quirements cannot be fully met an
the available colour range is sti
rather limited.

Today, for most types of fibre, th
basic dyeing problems can be regard
ed as solved. However, this does n
exclude the possibility that when di
ferent fibre types are used, speci
questions may arise which often ca
for extensive preliminary trials. F
polypropylene and polyethyle
which are processed industrially i
large amounts, dyeing is possib
only by adding pigments to the gra
ulate during the spinning proces
Consequently it is only economic
to colour such fibres if this can b
done on a large scale.

When braids made from synthet
fibres are to be piece-dyed, this pr
sents the braider with some prob
lems: it is a well-known fact that ce
tain fibre types shrink under the effe
of high temperatures, and this has t
be taken into account when con
structing the braid; a none too eas
task with ropes of the heavier so
(5 mm diameter and more). This tem
perature effect and, consequently, th

shrinkage also starts on the outside and moves inwards. With the thicker braids this leads to a structural shift which is detrimental to the regularity of the load-bearing properties. Continuous methods are suitable for dyeing braids only to a very limited extent. In the first place, the amount of material to be dyed is not always sufficient for economical operation and, secondly, shade variations are considerably more pronounced in heavier items, because the dye molecules tend to move towards the points where the temperature is highest. Endeavours have been made to eliminate this latter fault with the aid of a new, continuous dyeing and fixing process in which the braids are subjected to contact heat treatment on each side alternately. However, in the interests of quality, strand-dyeing is still preferred in many cases, provided that the gauge of the braid permits this.

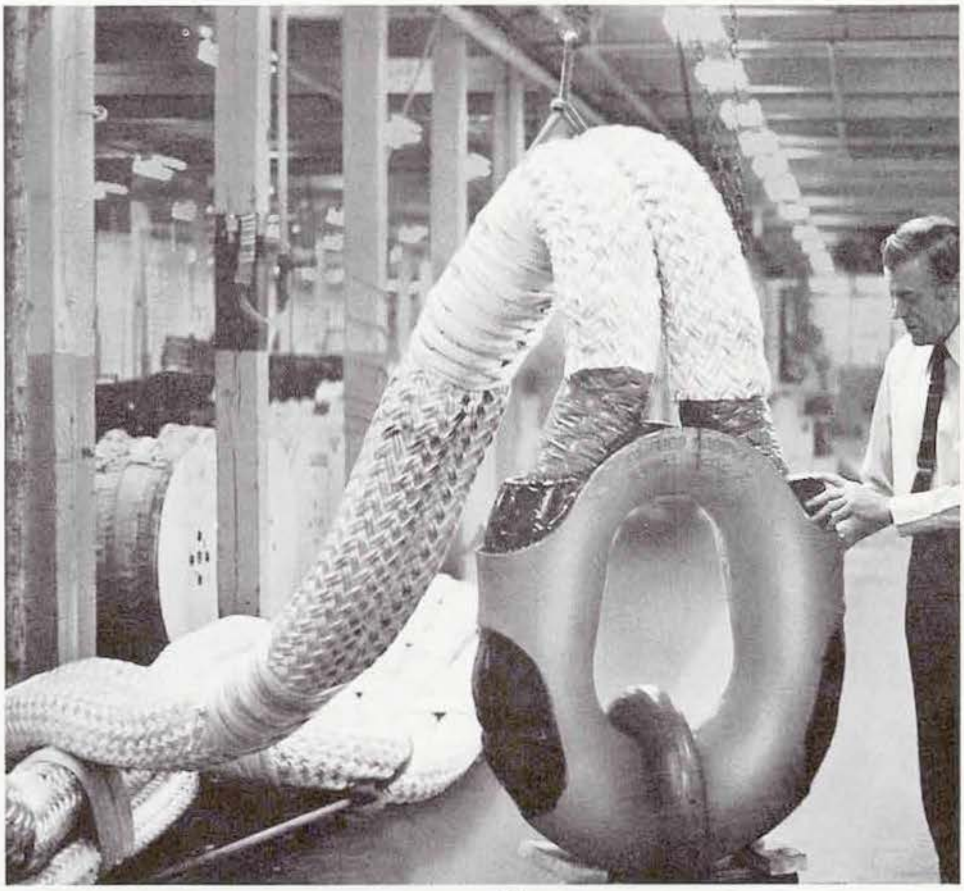
Similar problems are also encountered in impregnating. For example, finishes to improve the abrasion resistance of harness cords require baking at temperatures around 160°C. In this case also, measures have to be taken to counter the shrinkage by appropriate choice of fibres and by adopting the right structure for the goods. In addition to conventional wet processes, processing in nonaqueous solvents – for water-repellent finishes on special braids, for example – has been used with considerable success.

Making up

Braided ropes of larges sizes for industrial and marine use have to be made up in various ways. While it is very easy to splice loops or hooks into twisted ropes, with braided ropes the numerous individual elements make it quite a different matter. In fact, with core-sheath ropes manufactured on machines with a high spool count, such splicing is impossible, since the structure does not permit inclusion of the core in the splice. Mechanical aids such as those used in the wire cable sector where an aluminium compression ring replaces the splice are not at all suitable for textile braids, due to the dimensional changes which occur under loading. A nylon braid, for example, becomes longer and thinner under loading. The pressure that holds the loop together becomes progressively less as the load increases until, finally, the end of the rope slips out of the compression ring.

The situation with square braided ropes is quite different: Since transmission ropes first appeared, techniques have been known which permit a perfect loop to be spliced without any thickening of the rope itself, or ropes to be spliced together to form a sling. The basic principles of these techniques are, in fact, the same as those applied in splicing twisted ropes. An elegant method has been found of splicing loops or slings into double braids, so that no free end is left. In simple terms, the two individual braids are separated, a loop is formed, and the upper braid is worked into the lower as an inlay and vice versa. This type of loop can be made with ropes of even the largest diameter, and practically the full load-bearing capacity is maintained (Fig. 50).

For ropes that are permanently under tension (e.g. web leading ropes on the paper machine), circular braids without a score can be spliced to form an endless ring. The loosely braided rope end is beaten in to form a large hollow cavity. Some 40 to 50 cm of the second rope is drawn into this cavity. The other end of the first rope is then drawn into that of the second rope in a similar way. This splice is strong and very quickly made.



50
Heavy duty double braid with spliced eye and thimble (breaking strength of over 1000 tons).
Photo: Samson Cordage Works, Boston/Mass. (USA).

Figures without acknowledgement were provided by the author.

The Japanese art of braiding

by Noémi Speiser

Cords and braids

Even the casual visitor to Japan is ikely at some time or other to visit one of the popular department stores, where, perhaps, the main attraction will be the kimono department which generally occupies a whole floor. Here, amidst the numerous, someimes fantastically beautiful and, to he stranger, often puzzling components of Japanese costume, he will ind a large selection of braided silk cords. There are two distinct types of cord: One type is about two yards ong, approximately a fingerbreadth n diameter and has a neatly packed assel at each end. The second type consists of two tiny, paired or knoted braids both of which have a loop at one end and a small tassel at the other. Depending on the quality, these cords may be displayed hanging free on racks, or prettily tied and mounted on cardboard, or carefully arranged in cloth-lined wooden boxes.

A quick glance round the store, takng in a model exquisitely dressed in a party or bridal kimono, or, perhaps, a customer tripping along in her simpler day kimono, will soon reveal the purpose of these cords: The arger one is used to secure the complex bow of the *obi* (the stiff brocade belt) in the back. It is drawn tightly round the body and tied in front in a reef knot, the ends being tucked in at the sides. It is called an *obi-jime* or "that which holds the sash together" (Figs. 52, 53).

The smaller pair of braids, on the other hand, is meant for the lapels of the outer garment, which fall down vertically from the shoulders. The lapels are provided with two loops of material to which the loops of the braids are attached (Figs. 51, 54). These *haori-himo*, or "outer-garment-cords", are tied over the chest.

Both these products are examples of the age-old craft of *kumi-himo*, or "cord construction".

Only comparatively recently have braids come to be used for ordinary women's clothing. The craft was at the height of its fame much earlier, in the days when Japanese warriors wore armour made up of hundreds of small metal, leather or lacquer plates joined together by dark blue or red braids, when they wound their helmets round with cords and each warrior, even when "off duty", wore two swords embellished with long braids.

Braids were also used on scrolls, on metal mirrors, on the famous *inro* with its *netsuke* and on many other articles. With few exceptions, none of these uses is relevant today.

In the Meiji Period when the Samurai finally lost even the right to bear arms, the silk braiders realised the precarious position of their craft and began to look for new areas of application. The fashion of the braided *obi-jime* was launched, to replace the quilted constructions with which women had up to that time secured their sash bows. Thus, braiding changed its male custom for an almost exclusively female one. Profound knowledge of the technical possibilities enabled the craftsmen to develop a whole series of fashionable fancies from the austere patterns of earlier eras.

Background

All the information on Japanese braiding presented in this article is based on personal field research. Wherever braids were offered for sale – in department stores, on temple markets or in exclusive shops – they were examined in detail piece by piece, and a sample of each type was purchased. In addition to this, many craftsmen kindly donated experimental fragments.

Such a collection is of inestimable value for a study of the techniques employed. For a verbal explanation of complicated technical concepts is difficult enough, even in a common language – in Japan, the visitor would find it almost impossible. Questions which appear sound and relevant to a mind programmed for Western logic, may lose all validity, even when translated by an excellent interpreter. In these situations, the most insignificant fragment can help to reveal many trains of thought and explain how a new design is derived from traditional basic patterns.

Hand-braiding and machine-braiding

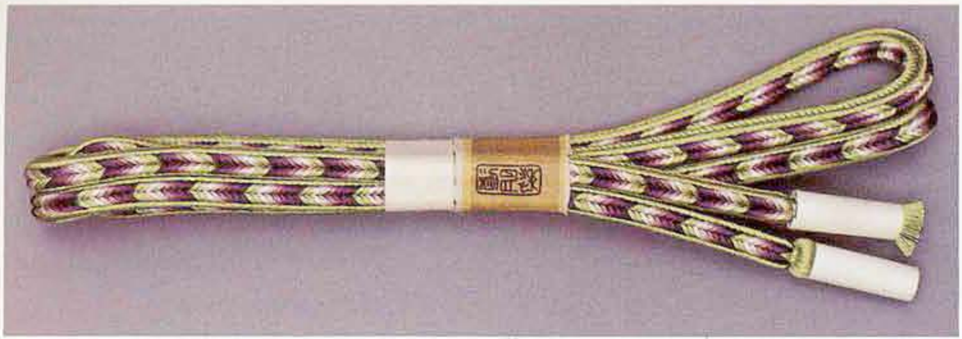
Comparative study shows that the structure of most Japanese braids and cords is basically the same as that found in the products of Western braiding-machines. Technically speaking, they are either flat or tubular, diagonal braids. The threads run in one, two or more courses of circular or multiloop form in zig-zag (braids) or reverse helical (cords) patterns through the structure, thereby interlacing with each other.

Thus, we see that the construction of Japanese hand-made braids follows the same principles as that of industrial braids. Consequently, traditional patterns can be copied without difficulty on the braiding machine.

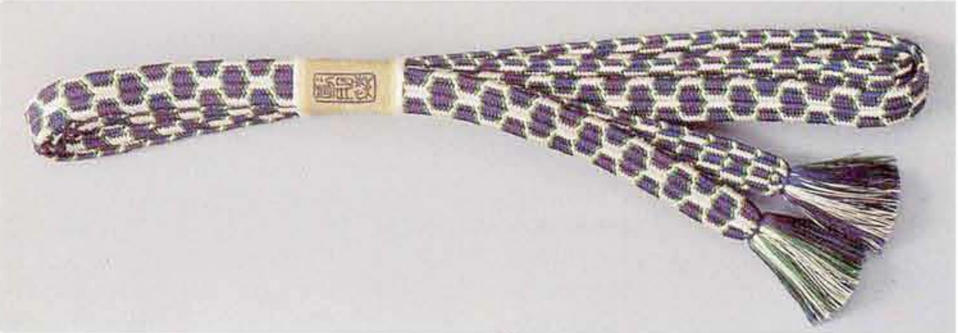
However, this is not quite as obvious as it may appear to the reader well acquainted with industrial braiding: If we examine Peruvian cords, for example, we will see that these do not follow any uniform system and that the majority could not be copied on any machine. And here we are concerned only with those constructions worked with stretched threads, ignoring the many types of cord involving knots and stitches.

In Japan today, a part of the overall cord production is manufactured by the braiding industry. However, with a little experience it is easy to distinguish the machine-made product from the hand-made product: The

51
Japanese woman in ceremonial kimono in the temple court. The outer garment is held together by *haori-himo* and just above these the *obi-jime* is visible.
Photo: E. Schulthess, Forch/Zurich (CH).

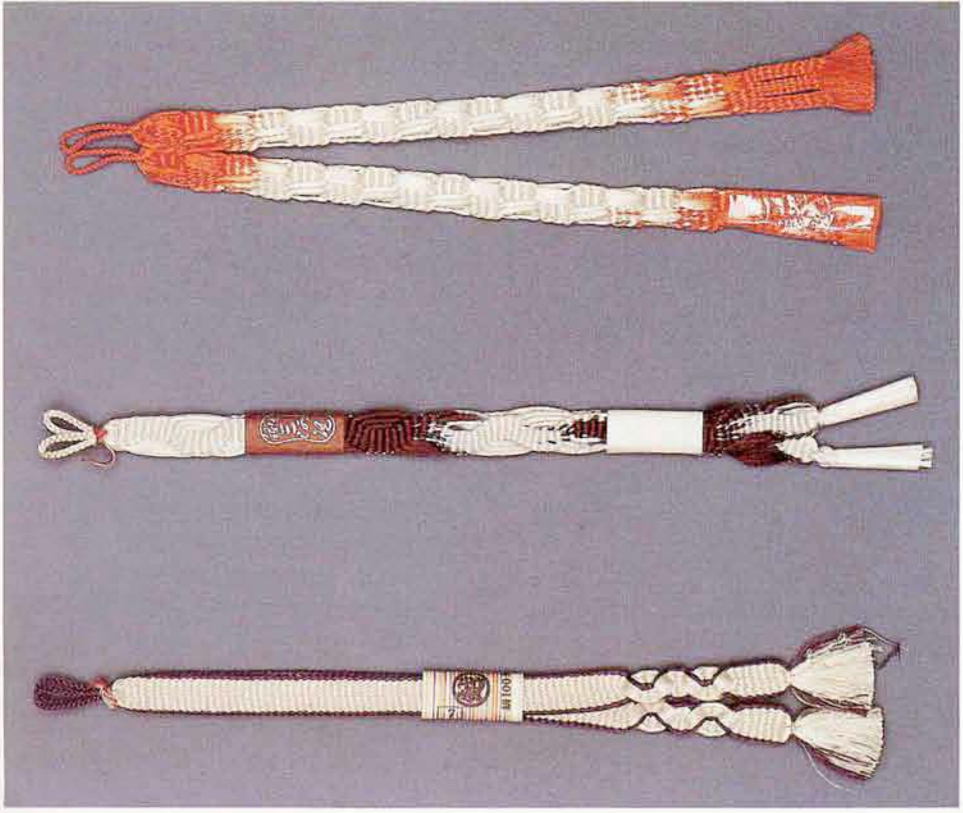


52
Obi-jime in the classic *maru-genji* braid worked on the *maru-dai*; length when opened approx. 150 cm.



53
Obi-jime in the *kikko* pattern, emblem of the turtle which symbolizes a long life and a happy old age (double braid worked on the *taka-dai*). In the colours depicted here this pattern was used to decorate the armour and swords of the Samurai.

54
Outer-garment cords – *haori-himo* – worked on the aya-take-dai (see p. 32); length approx. 16 cm.



former usually contains one or more cotton cores and has a harder handle. In use, an *obi-jime* always has to be tied in the same place. Industrially produced cords are less able to withstand this strain than the supple hand-made products. However, there is obviously a great deal of care taken with machine-made articles also, and industrial collections include a large number of sophisticated and delightful designs.

Braiding centres

The braiding of kimono cords is carried out exclusively in Tokyo, in Kyoto and in the regions adjacent to these cities. The whole of this immense country is supplied by these centres. Productions units consist of small family set-ups, as well as workshops some of which have machinery at their disposal.

Admission to these workshops most of which have been run by the same family for generations, can only be gained if one has the right references. Without ready support from many quarters, this study could not have been pursued as far as it was. However, if the examiner is keen to recognise the fundamental principles of a textile structure and its production, and particularly if he has some specialist knowledge of similar techniques, he will handle the braid differently to the layman and follow a work-process much more closely. It would appear that the hosts observed the genuine interest of their visitor, for they continued to disclose more and more fascinating details, posed willingly for photographs and followed the hastily drawn sketches with much pleasure.

Braiding material

Very fine, three-ply silk, worked from ten to more than a hundredfold depending on the type of braid, is the sole fibre material used. These plied threads have the advantage of possessing a smooth surface, thus giving the appearance of untwisted material. At the same time they are still stronger than the lightly twisted yarns used in older braids. If the nature of the braid calls for some kind of twist, this is imparted to the threads immediately before braiding by turning the bobbins and renewed continually in the course of the working process. This carefully worked-in twist is an important factor for quality.

Waku and bo-dai

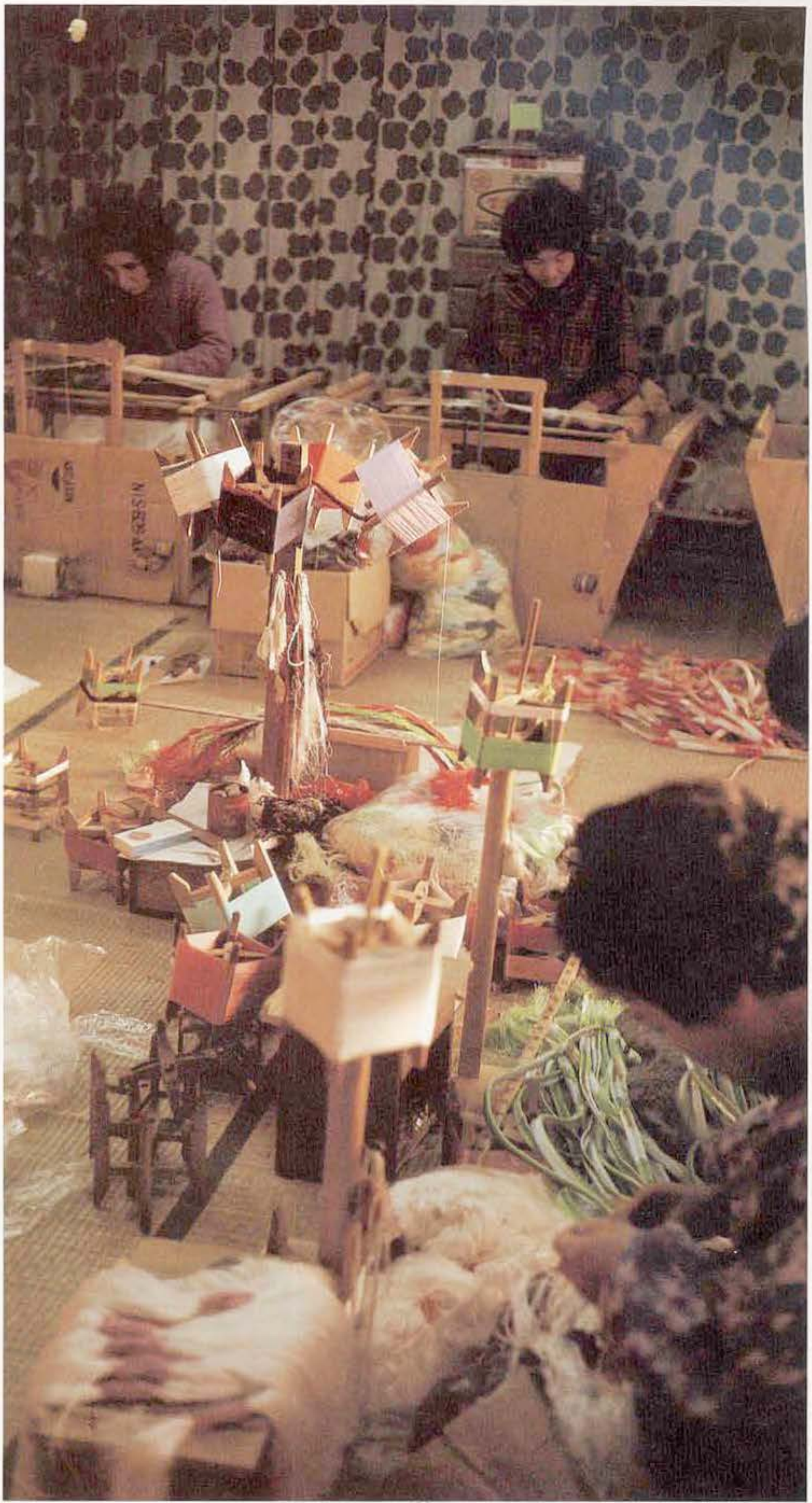
From the silk hanks the threads are wound on to pretty reels called *waku*. These *waku* are to be found in every textile workshop, piled high like miniature towers when they are loaded and hanging from the ceiling like bunches of grapes when empty. They also occur in daring combination with plants, ribbons and many fresh products of the inexhaustible Japanese imagination as a popular decorative motif on textiles, as well as on articles of lacquer and metal.

For winding, the *waku* can be turned on special frames either by hand or with the aid of an electric motor. A craftsman of the old school, however, puts the *waku* on a rod and spins t round with his open hand. This rod becomes as shiny and smooth as glass due to the constant friction.

An essential and very versatile piece of equipment in the braiding workshop is the *bo-dai* or "pole device" Fig. 55). This consists of a massive wooden block in which one, or someimes two or three, vertical poles are et. The pole has a small hole at the op, into which variously shaped metal pins can be inserted, to serve as supports for bobbins, reels, hooks nd-loops of cords etc. The bulky *bo-dai* is brought out, not without coniderable physical effort, for the most aried purposes.

Warping

Before the actual braiding process an begin, the warp must be prepared. The loaded *waku* are set up on the floor in rectangular patterns. he threads run up and over a bamoo rod which is hung horizontally elow the ceiling in every workshop, nd then run down to converge in the ight hand of the kneeling craftsman. e draws down the sheet of threads nd guides it back and forth, with



55
Working atmosphere in a braiding workshop: loaded reels *(waku)* and pole devices *(bo-dai)* can be seen everywhere; dyed warps with tye-offs lie in the foreground, while in the background two braiders are working on the *taka-dai*.

expansive movements, between the upstretched fingers of his left hand and the *bo-dai* (Fig. 55). In the course of this process the left hand has to be held constantly at a fixed distance from the *bo-dai*. It must not alter its position in the least throughout warping, otherwise the tension in the threads will vary and these may become entwined in such a way as to be impossible to re-arrange in the correct order. Each individual beer is carefully separated from the next with the aid of a loop of cotton.

As one can imagine, this traditional method of warping demands considerable physical discipline of the craftsman, so that it is being replaced more and more by the simpler technique of using fixed wooden pegs.

Close examination of a *haori-himo* reveals that the threads of the braided loop are also incorporated in the adjacent cord. This leads one to the astonishing realisation that each piece must be braided separately. The same is also true, in fact, of the *obi-jime*. Thus we see that in the hand-braiding workshop they never work in yardages, but a special warp of the required length is prepared for each individual cord.

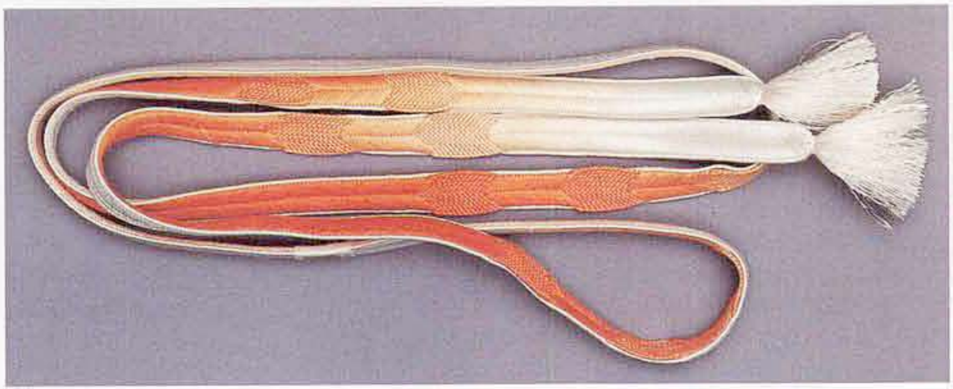
If the braid to be made has only one colour or is to consist of continuous differently coloured threads, the planned colour arrangement is naturally taken into account during warping.

However, many braids display changing colour effects along the length of the cord. In this case, the warps for a certain number of cords of identical design are prepared and bundled, the areas to be resisted covered with plastic and rubber bands, and the whole is laid carefully in small dyebaths. For gradual colour changes, on the other hand, the warps are not resisted but immersed little by little in the dyebath under careful supervision and gradually drawn out again. This type of dyeing is very highly regarded in Japan (Fig. 56).

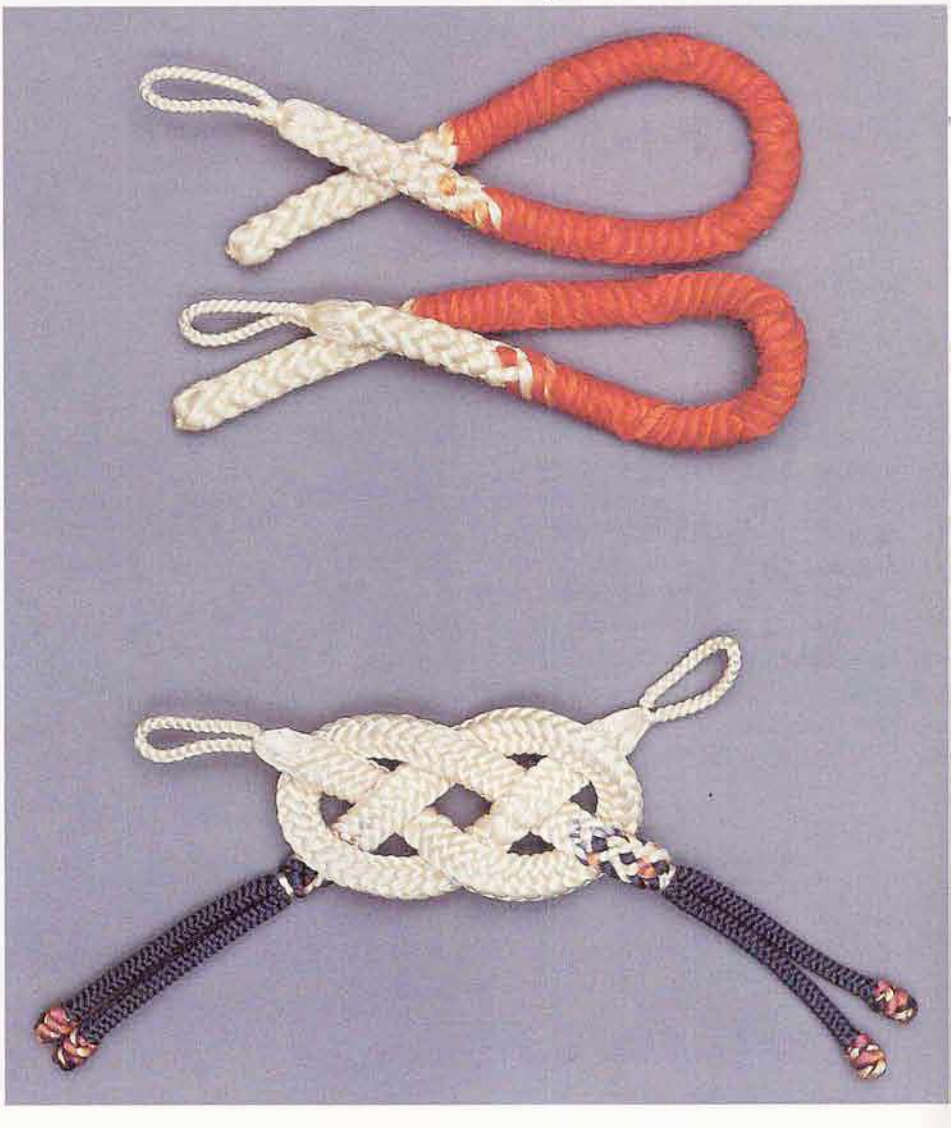
The inumerable intricacies of the colour effect, often in direct interplay with the pattern of the braiding, have to be planned down to the last detail in advance. Craftsmen will take the greatest pains, regardless of the time consumed, to perfect some tiny detail. Anyone who runs through in his head every single work stage for any of the pieces illustrated, will be faced with a completely novel attitude to work: instead of simplifying the processes as much as possible, the Japanese craftsman appears to go out of his way to find new difficulties.

Braiding bobbins

The yarn supports used in braiding are bobbins. All bobbins used on the devices described in the following have the same basic form, though they differ in weight and dimensions. The heaviest can weigh up to a kilo and are made of clay. All others are turned from wood, their cores hollowed out and filled with lead, and



56
A double-layered *obi-jime* with gradual colour change (no visible steps), braided on the *taka-dai;* length when opened approx. 150 cm.



57
Artistically dyed and braided pairs of *haori himo* (slightly enlarged).

alibrated to a particular weight. They have no edges on which the hreads might rub or catch (Fig. 59). Now comes the next stage after warpng. Each warp thread is wound round a bobbin and fixed with a loop. The uspended bobbin automatically asumes a horizontal position. In order o reduce the wastage of expensive material to a minimum, bobbins are provided with a certain length of coton yarn which is never wound off. The silk warp threads are attached to he end of this by knotting.

The braiding process

When all the warp threads have been wound onto bobbins and their free nds knotted together, these are aranged on a braiding device and braidng can begin. In many cases, the actual braiding process requires only very little time, which makes the long preparatory processes seem somewhat disproportionate. Yet, there are also braiding patterns of subtle complexity which require a great deal of skill, time and patience.

On completion of braiding, the warp ends are untied from the bobbins and he product passes into other hands for further processing. By tying off irmly and fixing vertically with the aid of a needle, the loose ends are formed into a tassel and pressed unler steam.

At this stage the wholesaler takes over and is responsible for adding the inal touches to the braids, packing and presentation (Fig. 58).

Maru-dai

(the round device)

The *maru-dai* is a circular braidingable with a hole in the centre (Fig. 60), standing on legs about 18 inches high. The braid is formed by crossing he threads in the horizontal plane either simultaneously or one immediately after the other – in the same way as on the braiding machine. The working threads are spread out radially round the table, with the bobbins hanging down over the edge on all sides (Fig. 59).

There are two basic methods of braiding which can be applied starting from this position:

Method one: The ends of the warp threads, which have been knotted together, are drawn down through the central hole with the aid of a counterweight. As the braid is formed, it is drawn down through the hole in the centre of the braiding table (Fig. 59) and thus "grows" in an upward direction (the "shed" is open on the top side, Fig. 61).

Method two: As the braid is formed, it is drawn upwards and "grows" in a downward direction (the "shed" is open on the under side).

Depending on the intended structure of the braid, the threads are arranged in groups in a certain way. These groups exchange elements continually in the course of the braiding process, threads being removed on one side and added on the other. The threads are gripped just below the table top, raised slightly and moved to the left or the right round the edge of the table (Fig. 60).

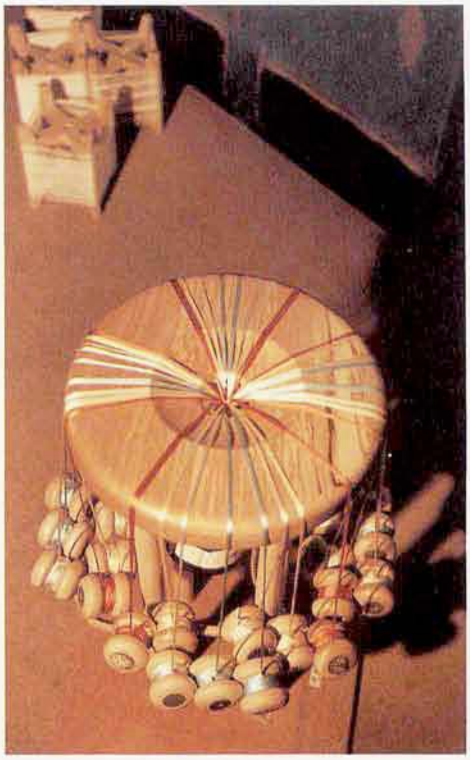
In this type of braiding both hands are evenly occupied in regular, symmetrical movements. During the working process the braider uses every one of his fingers: depending on whether his hands are close together, far apart or gripping their threads in a crossed-over position, and in which direction the threads have to be moved, the index finger may serve as a hook or, together with the thumb, as a gripping tool, the middle finger may slip under the thread and hold it fast against the ring finger, and – in whichever way the bobbins are transported to their new positions – in the same movement the other fingers will push the remaining threads of the group in question into position.

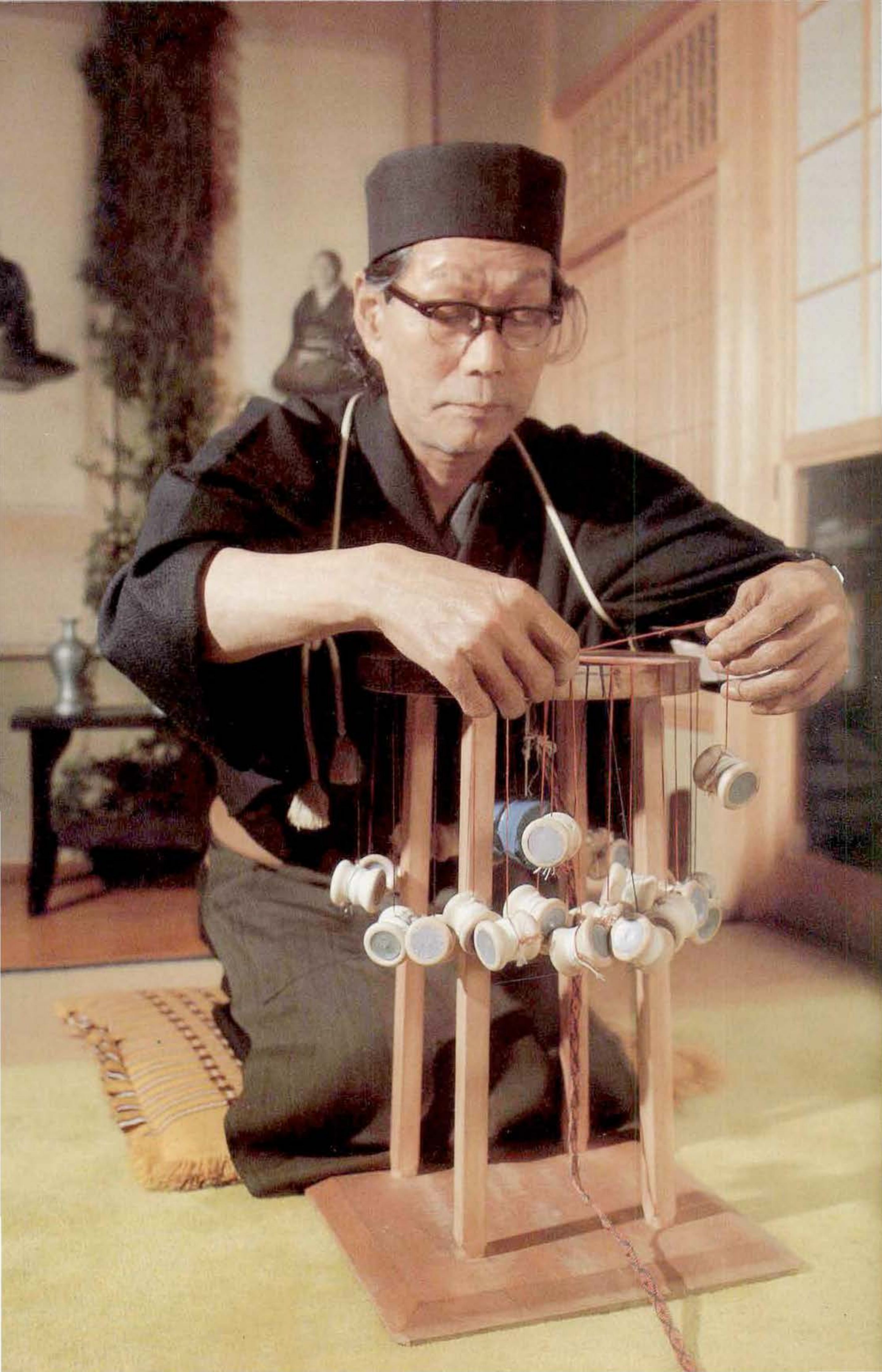
Care is also taken to ensure that the tension in the braid is evenly distributed as it builds up: at regular intervals, the back of the hand is slipped under the hanging threads of the rear groups. These are raised slightly above the edge of the table and, by withdrawing the hand sharply, the full weight of the bobbins is allowed to drop. The same treatment is given to the threads at the front. During this process, the heavy weight of the bobbins and the reverse pull of the counter weight cause the threads to adopt the desired, complex helical arrangements and the surface of the braid becomes smooth and even. This process is accompanied by a gentle crunching noise.

Clearly, the *maru-dai* where the braid is drawn down is a very simple device,

58
Making up and packing braids ready for dispatch.

59
Braiding table of the *maru-dai*. The bobbins hang in a close circle from its edges and prevent each other from turning.





on which work can be done in a quite small space without any further equipment. With the bobbins hanging all round and the counterweight in the centre, it is evenly loaded and perfectly stable. Furthermore, its round shape means that it is not predetermined for any particular kind of braid but can be used for the most varied patterns.

The well-ordered movements of braiding require considerable involvement of the whole body of the kneeling craftsman, and the strictly regulated work process immediately assumes a certain rhythm. This helps to build up a clear mental picture of the braiding process, so that the movements involved in even the most complicated patterns can be clearly perceived and understood.

Kakku-dai

(the square device)

In contrast to the *maru-dai*, this braiding table is square and usually has a vertical spike in the centre in place of the hole in the *maru-dai* (Fig. 61). The knotted end of the prepared warp is placed over this spike and the loaded bobbins are allowed to hang down at the sides of the table. After a few braiding movements have been completed, the knot is connected by a cord to the counterweight which draws the braid upwards as it is formed. A horizontally suspended bamboo rod with a slit in the front prevents the braid from twisting.

All these devices must be exactly coordinated, since the braiding table is held more or less upright only by the suspended bobbins. If these are not raised and lowered again with precise, simultaneous movements, the table will lean and may tip over.

Though the braiding movements appear to be the same whether the braid is drawn off in an upward or downward direction, they do in fact have a different end-effect: If the braid is drawn off downwards, when a bobbin is displaced its thread will pass through the centre of the growing braid. If the braid is drawn off upwards, however, the same movement takes the thread over the surface, so that only hollow braids can be created in this way (Fig. 62).

Naiki-dai

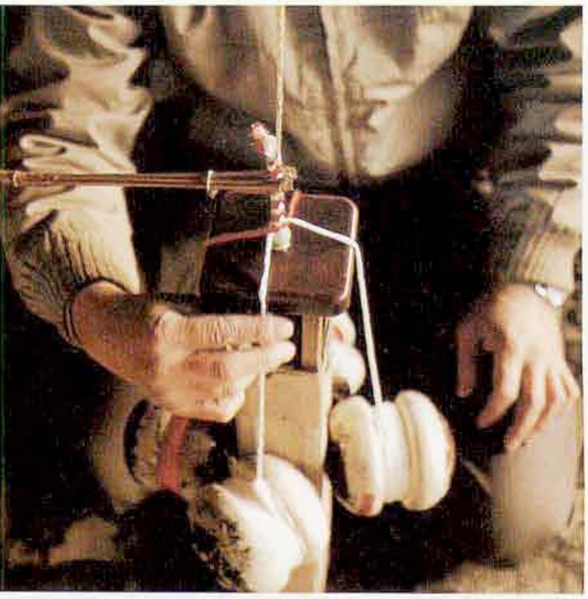
This device is built completely of wood and makes such a peculiar noise when in use that it has also been given the onomatopoeic name "gachia-gachia". Once the machine is set up and loaded, the operator has no further physical contact with the material to be braided: all he has to do is move a lever back and forth continually and the pattern is braided automatically. How the device works can be seen from the plan view and cross-section in figure 63.

One cannot help but smile when faced with this braiding machine in action: accompanied by a deafening clatter, the wooden paddles – ranging in size from very large to tiny – revolve like a swarm of ponderous beetles. Their movement is not at all fluent, but rather jerky due to the rough cog-wheels that drive them. By means of the hooks which it carries on both sides, each paddle picks up a thread from the radially spread warp, holds it with the "shoulder" and continues to transport it until, drawn by the weight of the bobbin, it slips down over the end surface of the paddle and is guided unerringly into its predetermined slot in the braiding table.

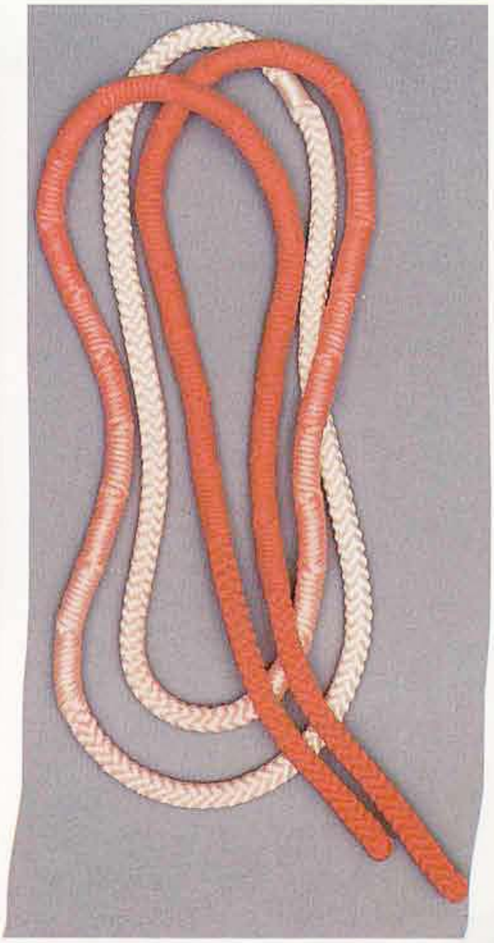
The threads transported by the largest paddles are deposited last of all, while the smaller paddles – completely hidden by their "big brothers" – have long since completed their allotted task. Not until all the warp threads have settled in their new slots can the lever be moved in the opposite direction. For, unlike western braiding machines, the *naiki-dai* moves only one sheet of warp threads at a time, while the other remains stationary.

With carefully-planned arrangement of various paddles and with the aid

60
Working at the maru-dai.
The growing braid is drawn off below the table.
Photo: With kind permission of F. Ohta, Otsu (Japan).



61
Kakku-dai, the square table.
Before braiding the threads are given a certain degree of twist. The finished braid is drawn off upwards.



62
Obi-jime made from a sheath-core braid with eight threads, worked on the *kakku-dai*.

of further accessories not described here, it is possible to obtain a large number of different patterns, though they are all hollow braids consisting of two contra-running circuits which can intersect as often as the designer wishes.

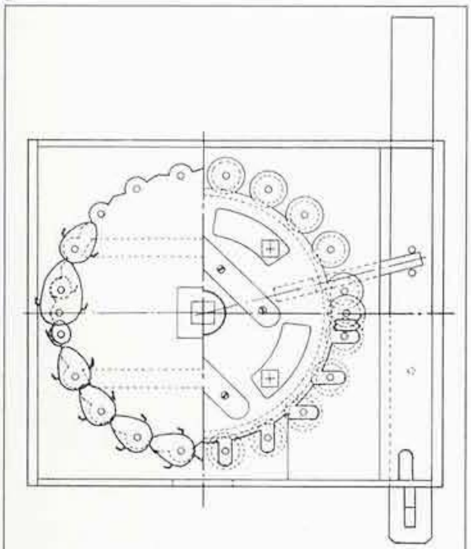
Taka-dai

(the high device)

The *taka-dai* is used for making flat, diagonal braids (piping). The braider works kneeling on a raised board, and the bobbins hang low, so that a lot of thread can be wound off and the braiding process need not be interrupted so often (Fig. 64).

The braid builds up in V-shape towards the braider and is drawn off in the opposite direction. The warp threads are spread out fan-like half on the left and half on the right, each individual thread lying between pegs set in rows along the side beams of the structure (Fig. 64).

63
Plan view and cross-sectional view of the *naiki-dai*: a large central cog-wheel sets the smaller peripheral cogwheels in motion, whose axes carry eccentrically placed wooden paddles which act as thread guides.



Since the braider always passes the rearmost thread of the "fan" through all the others and then lays it on the opposite side at the front, the sheet of threads comes gradually closer and closer to him. Once the foremost pegs are occupied, he would have to move them back thread by thread to create working space, if the *taka-dai* did not offer a most original solution to this problem: each consecutive series of six pegs is in fact set on an individual "sled", the runners of which engage in a groove in the side beams. When six passes have been made on each side, the rearmost sleds – now empty – are lifted and placed right at the front, pushing the remaining sleds back.

The device is also fitted with two additional side beams, somewhat higher and further out than the others, which also carry sleds. This arrangement makes it possible to include further, floating threads in the braid, or to produce two-layered or tubular braids (Figs. 65, 66).

If the pattern requires that these two layers be intermingled, then bobbins of the upper layer are swapped with bobbins of the lower layer. This demands considerable manipulative skill. The arms must be raised in a strictly controlled movement and lowered again in just the right place, because if the bobbins start to swing they may catch on the spread-out threads and the braider has no hand free to guide them into their allotted spaces (Fig. 67).

Due to the continuous contact with the precious silk, the perfect symmetry of each movement, the varied interplay of the hanging bobbins and the periodic displacement of the sleds, which are firmly grasped and replaced with a loud clatter –, braiding on the *taka-dai* is a fascinating procedure in which mental and physical mastery of the working proces are in perfect harmony.

Aya-take-dai

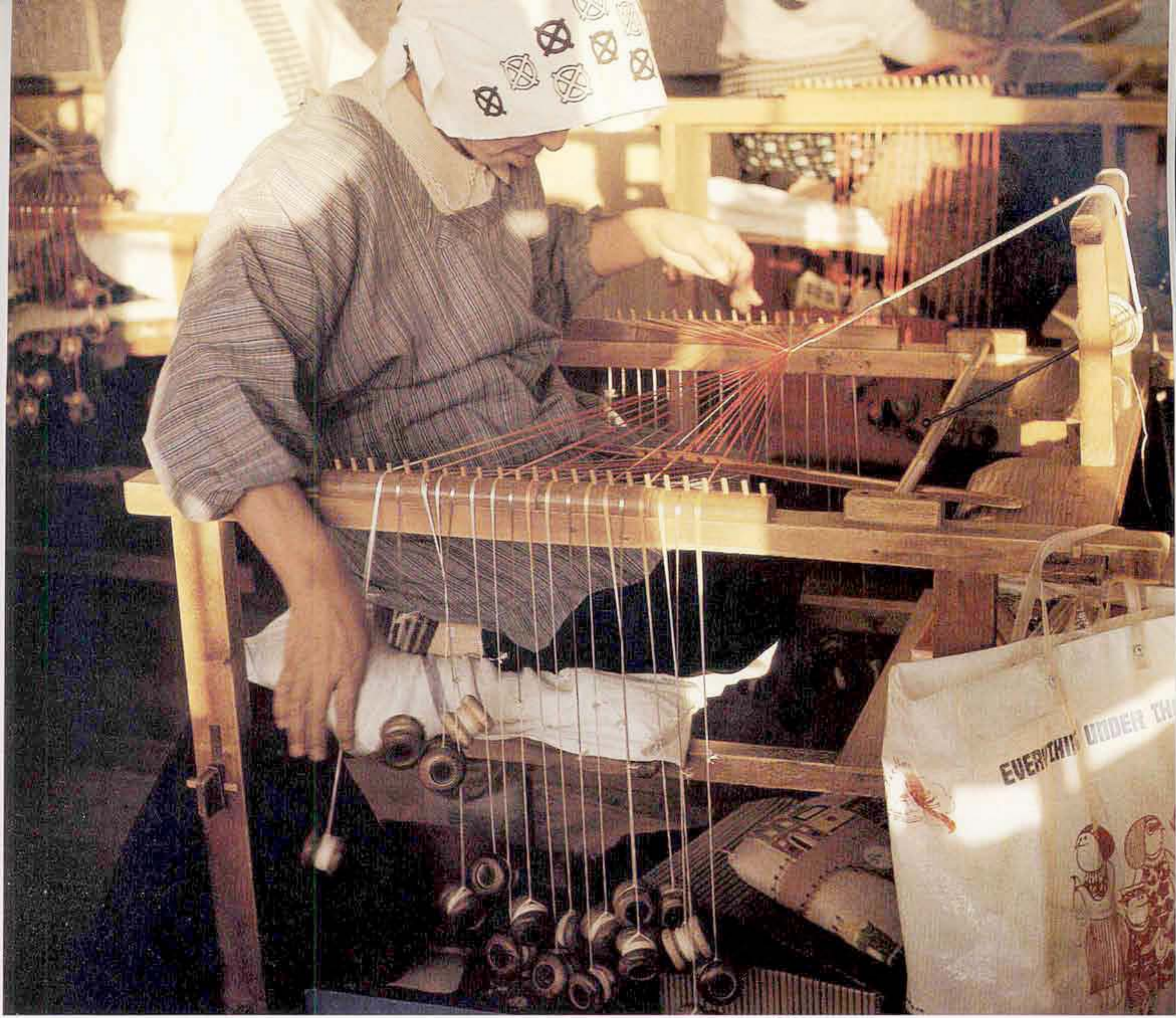
(twisting device made from bamboo

This clever little device is not designed for making diagonal braids The craftsman works with two systems of threads, which are clearly recognisable as warp and weft and never exchange functions. However the warp is not fixed at both ends a in weaving but is wound on bobbins as in the other braiding methods These bobbins are suspended from the breast beam. The braid grows towards the braider and is drawn of in the opposite direction.

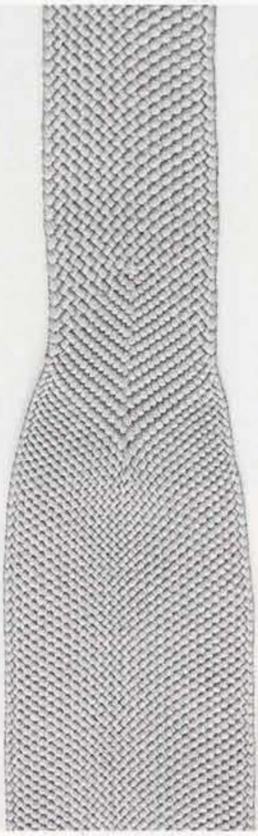
On the *aya-take-dai* so-called twining of the warp is produced, i.e. a group of simultaneously entwining pairs of threads is joined together laterally by a weft thread at each half-turn.

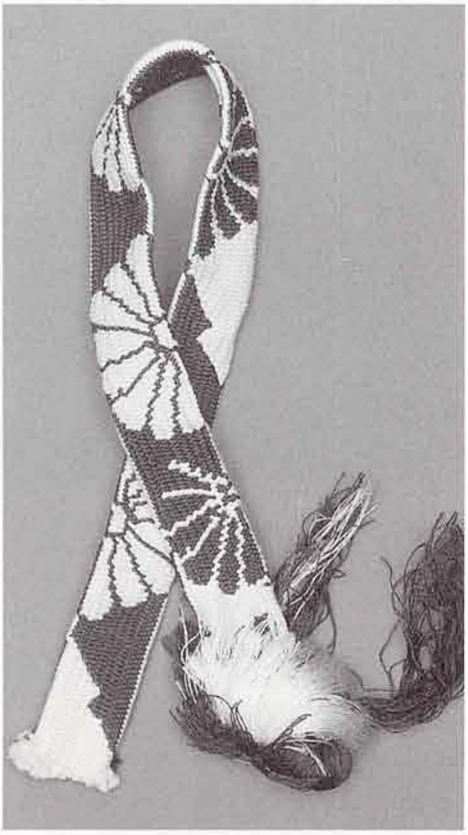
In order to achieve this entwining of the pairs of warp threads, the device is fitted with a very clever arrangement which astounds with its simple yet most effective design: The breast beam is fitted with a row of wooden pegs finely carved into a feather-like shape and inclined slightly towards the braider. One thread of each of the two pairs to be entwined lies on the breast beam to the left and to the right of the base of the peg, while the remaining two lie higher up on its shoulders. Thus arranged, the warp threads as a whole form a shed.

The shed is changed in a symmetrical two-handed movement (Fig. 68). Each hand draws one of the outside threads positioned on the breast beam, carefully up along the edge of the peg between the appropriate upper threads until on reaching the shoulder they displace these upper threads which fall with a dull thud on to the breast beam, pulled down by the weight of their bobbins. With this manoeuvre, then, one of the upper bobbins has fallen over the corresponding lower bobbin in an S-turn and the other in a Z-turn. The whole process is carried out simply by this



64
Working at the *taka-dai.* Sleds fitted with pegs on the side beams support the sheets of threads.





65
Tie in European style braided on the *taka-dai.* Note the clean transition from narrow braid to wide braid.

66
Section of a picturesque double braid.

raising of threads. It demands no special manual skill, since it is guided throughout by the well-thought-out shape of the pegs.

When all threads have changed places in this way the new shed is open. The braider inserts a thin pick from each side and beats these in with a reed.

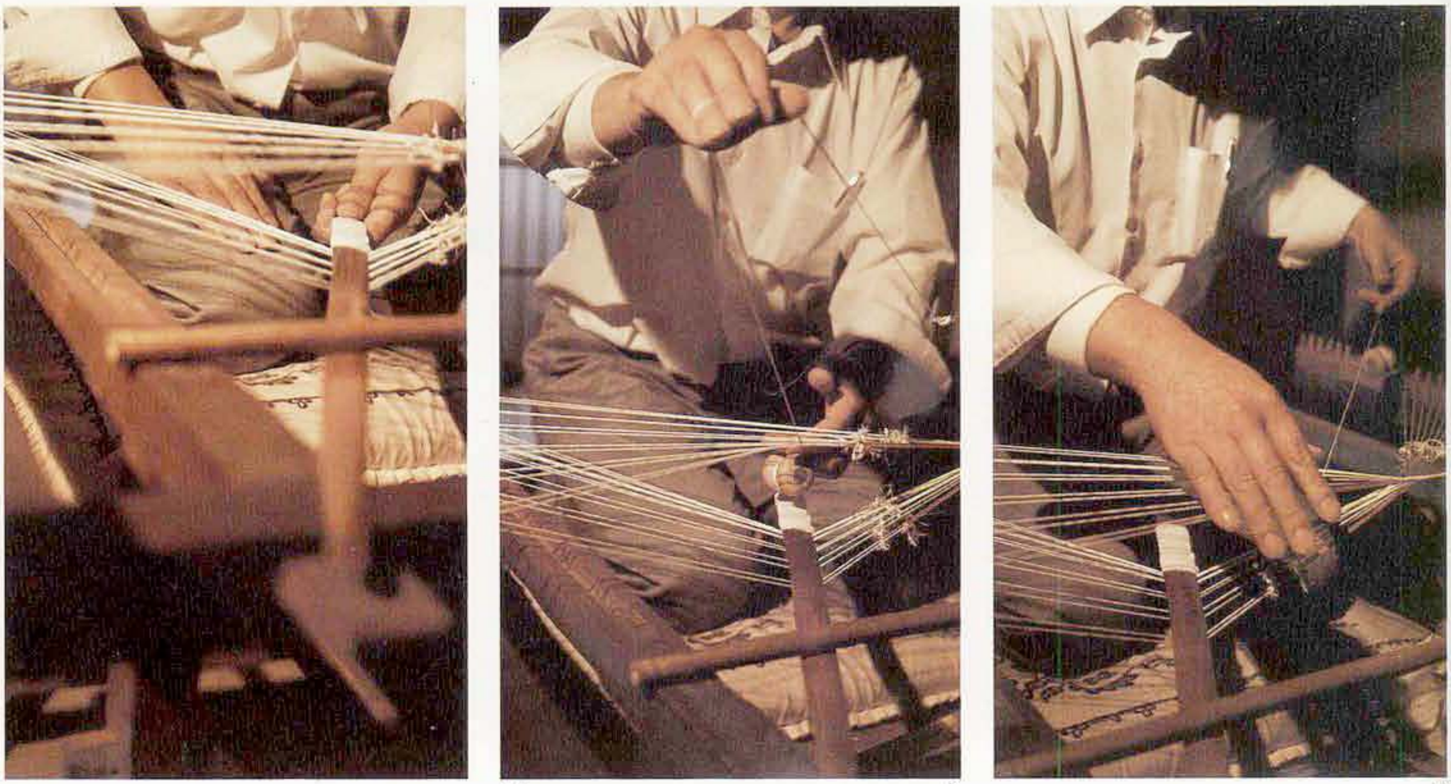
Kara-kumi

(Chinese braiding)

No review of Japanese braiding would be complete without a reference to *kara-kumi.* This technique came to Japan from China during the Nara period and has survived there through the centuries up to the present time. Only the Emperor and Empress, the Crown Prince and the three highest ranks of the Nobility have the privilege of wearing *kara-kumi* belts. One specimen is kept in the Shinto Shrine at Ise. According to an age-old tradition of ritual destruction and rebuilding of the shrine (Fig. 69), this must be replaced every twenty years, together with all the other treasures it contains.

Technically, the *kara-kumi* is a twining diagonal braid with several longitudinal paths and regularly recurring reversal points. Though braids of this kind are found in many countries, the *kara-kumi* occupies a special place, since it must conform to especially strict rules which cannot be modified or ignored under any circumstances. Thus, the structure of each belt is identical. Colours, on the other hand, may be used in an infinite number of different combinations, and the rules of braiding have been formulated in such a way that, depending on how they are grouped at the start, the colours will appear on the surface in the most varied forms.

The edges are multicoloured and the plain-coloured middle sections sometimes display resist dyeings, which enhance the adjacent edge colouring in various ways. Hard-twist silk yarns



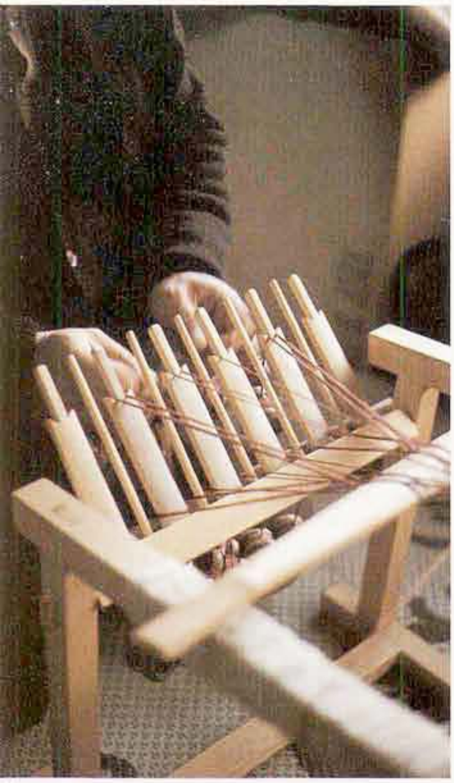
67
Braiding process on the *taka-dai:* a) the shed opened manually is held in place with the stave; b) the nearmost bobbin on one side is taken up in the left hand and swung through the open shed; to be caught in the right hand and placed as the foremost thread on the other side c).

are used for braiding *kara-kumi*. The twine has the same twist direction as the yarn, so that the structure is given unusually high inner tension.

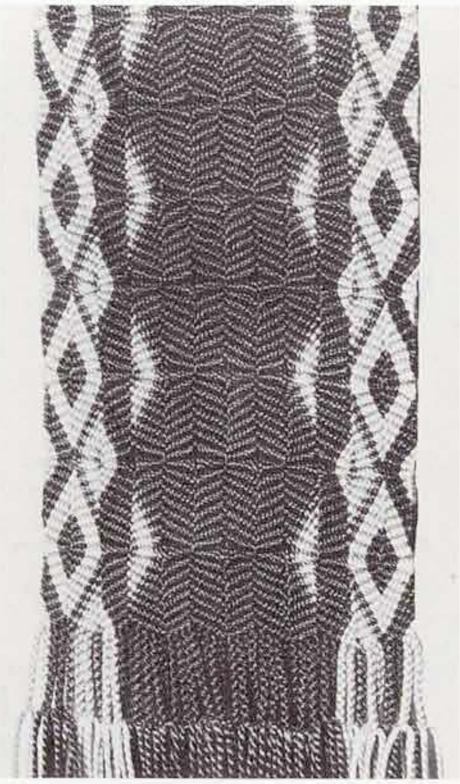
The working principle largely resembles that of European pillow lace work, but instead of a pillow a frame is used, fitted round the edges with pegs at intervals if about one centimeter. The – temporarily – passive threads are bundled and laid between these pegs. The braid is worked as tightly as the yarn will allow. While the braider, with deft fingers, intertwines the individual groups of six threads in a matter of seconds, he takes infinite care in tightening the yarn pairs and in ensuring that the individual sections of the braid are even (Fig. 70).

The test of true mastery

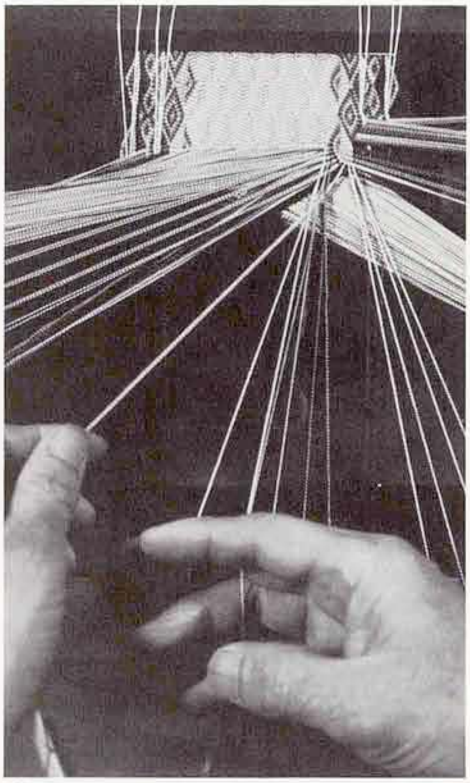
Though our research uncovered a considerable store of other inventions and unusual patterns, the devices and procedures described above are the most important and enjoy the widest usage. Shortly before leaving, however, we were taken to a master craftsman who was greatly famed among connoiseurs of the art. He maintained that the most difficult task of all, the test of true mastery, was braiding the simplest plait with three strands. He prepared the warp, wound it on to enormous bobbins, tied the ends together and placed them over the hook on top of the *bo-dai*. He then proceeded, with intense concentration and in powerful, rapid movements in which every finger had an important part to play, to manipulate the precious silk material into the appropriate curving forms.



68
Working on the *aya-take-dai*. The threads to be entwined lie on each side at the base and on each shoulder of the winged wooden pegs. The braider is just about to undertake the "shed change" with four pairs of braids simultaneously.



69
Kara-kumi belt of the narrow variety (section). These belts are 250 cm long. The broader variety are wound round the body after being folded three times. The ends hang down below the outer garment.



70
Kara-kumi braider at work.
Photos 69, 70: H. Ohmichi, Osaka (Japan).

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